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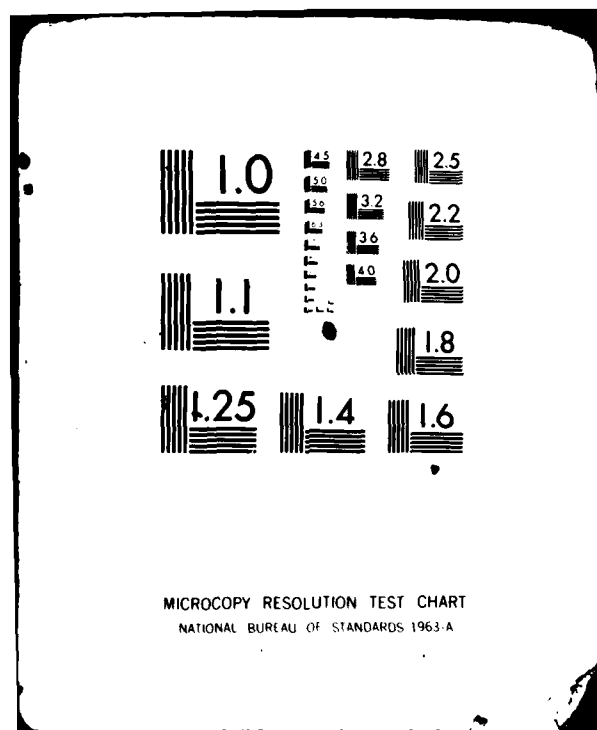
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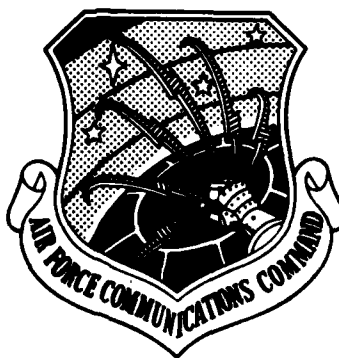
SPECIAL REPORT

A PROCEDURE FOR RTT POSITION IMPROVEMENT

USING LINEAR REGRESSION ANALYSIS

OF GLIDE SLOPE STRUCTURE

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DEPARTMENT OF THE AIR FORCE
1866 Facility Checking Squadron
Scott AFB, Illinois

30 May 1982

SPECIAL REPORT
A PROCEDURE FOR RTT POSITION IMPROVEMENT
USING LINEAR REGRESSION ANALYSIS
OF GLIDE SLOPE STRUCTURE
82/66S-277

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents a method to improve the position of a Radio Telemetry Theodolite (RTT) through an analysis by linear regression of the observed glide path structure of an instrument landing system. A complete derivation of the procedure is also presented, including examples testing the procedure at different glide slope facilities. These tests validated the procedure as well as revealed the limitations of its use. The procedure may be used to establish a permanent optimum RTT location for future use when commissioning new glide slope facilities exhibiting marginal performance and/or requiring Category II operation.		

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1. SUMMARY

1-1. **Background.** Probably the most argued item in glide slope performance analysis is where to position the Radio Telemetry Theodolite (RTT) to observe the flight inspection aircraft. Attachment 1 of this report provides an explanation of RTT operation and how they are used in glide slope flight inspections. Engineers generally agree that RTT position can have some effect on the recorded structure data; consequently, there have been many techniques developed to optimally position the RTT. My involvement in RTT positioning began in April 1978, when HQ Air Force Communications Command (AFCC) tasked the 1866 Facility Checking Squadron to investigate RTT placements along the runway edge minimizing parallax tracking errors due to being offset from the runway centerline. The results of our investigations were presented in the Wright-Patterson AFB Traffic Control and Landing Systems (TRACALS) Evaluation Reports, Nos. 78/66S-135 and 79/66S-166. I found our investigation had insufficient means to fully compare results at the various RTT locations. I could only compare average angle readings, or structure in the various Solid State Instrument Landing Systems (SSILS) zones. No indication of any pattern in the RTT placement could be determined until I tried analyzing the recorded structure data using a linear regression. Then I discovered the tilt of the linear regression indicated the position of the RTT relative to the linear regression. The ensuing three years have been spent collecting data from over 16 TRACALS SSILS Evaluations to investigate this phenomenon and developing equations to determine where to reposition an RTT for optimum viewing of the glide path.

1-2. Linear Regression Versus the Present Analysis Method:

a. The primary area where glide path structure is examined is in Zone 2, which is the area of the glide slope approach from 3500 feet to four nautical miles (NM) from the runway threshold. The recorded structure in Zone 2 is significant because of three reasons. First, it is the area where most troublesome anomalies occur. Second, a qualified theodolite operator can provide minimal aircraft tracking errors through this zone. Third, Zone 2 is usually the critical sector of the the glide slope approach where transition from instrument to visual approach occurs or where missed approach procedures are initiated.

b. The present method of examining Zone 2 structure is determining the average angle. This is the algebraic sum of the RTT eyepiece angle and the angular difference between the RTT eyepiece angle and the structure (differential trace). Structure occurrences are then measured from this average angle for Zone 2. In my opinion, the average angle method of analysis is inadequate because it will not depict or account for a trend in the angle data. Because of this inadequacy, it is possible for a glide path to have a structure occurrence within Zone 2 structure tolerances measured from the average but would exceed the tolerances when measured from the data trend. Consequently, a glide path could have an unsafe condition depending on the location and severity of the structure occurrence not accounted for with average angle analysis.

c. A more suitable analysis method is to apply structure tolerances from the data trend. This data trend can be established by fitting a straight line to the data. A best fit line can be derived using a linear regression by the method of least squares. This provides an equation of the form $Y = BX + A$, where A and B are constants. By using a programmable calculator, the linear regression can be found as easily as determining the average angle. Various programs to compute linear regression are presented in Attachments 7 thru 9. A more detailed discussion on the advantages and use of linear regression for glide path structure analysis is presented in Appendix I.

1-3. RTT Position Improvement Using Linear Regression Analysis:

a. Two TRACALS evaluations of the Wright-Patterson AFB, Ohio SSILS showed that RTT position can affect the recorded structure data. Primarily, the effect concerns the trend of the data. Our evaluations show that a data trend where the slope of the recorded structure decreases as an aircraft flies toward the threshold indicates the RTT is too close to the glide slope antennas. Conversely, a data trend where the slope of the recorded structure increases as the aircraft flies toward the threshold indicates the RTT is too far from the antennas. This implies a data trend where the slope of the recorded structure remains relatively constant will indicate an optimum RTT position and provide a truer indication of the glide path performance. The average angle will also correspond to the linear regression when the slope of the data trend is constant.

b. My procedure was developed to adjust the RTT position from an initial position so the recorded data will be relatively constant. The complete reasoning and derivation of the procedure is presented in Appendix II. The steps for the procedure are as follows.

(1) Collect the following information for the calculations.

d_{off} = Offset distance of the antenna base from the runway centerline in feet

d_o = Distance along the runway centerline from the threshold to the point abeam the antenna base in feet

s = Slope in terrain from the horizontal in front of the initial origin in degrees

Θ_{eye} = RTT eyepiece angle in degrees

(2) Set up the RTT along a line between the glide slope antenna base and the runway threshold centerline such that the RTT eyepiece is backsighted to the antenna base at the desired or commissioned angle.

(3) Perform an RTT structure run, recording the differential trace through Zone 2. This can be done as a normal RTT structure run through all three zones. An extra run for repeatability is desirable.

(4) Sample points are collected as coordinates with seconds as the X-coordinate and light lines as the Y-coordinate. The seconds should start at the glide slope antenna and proceed outward to the point 4 NM from the threshold (Point A). Sample points are collected starting 3500 feet from threshold (Point B) and proceeding to Point A. Sample the recording every two seconds and determine the light line deviation of the differential trace from the recording centerline at each sample point. Light line values on the 150 Hz side of the recording are considered positive. Those on the 90 Hz side of the recording are considered negative.

(5) Up to this point, this analysis is performed during a normal flight inspection. Now, find the best fit straight line to the series of sample points using a linear regression by the method of least squares. This is done using the following equations.

For (x_i, y_i) , $i = 1, \dots, n$

$$Y = BX + A \quad (1)$$

where

$$B = \frac{(\sum x_i y_i) - \frac{(\sum x_i)(\sum y_i)}{n}}{(\sum x_i^2) - \frac{(\sum x_i)^2}{n}} \quad (2)$$

$$A = \frac{\sum y_i}{n} - B \left(\frac{\sum x_i}{n} \right) \quad (3)$$

(6) The following equations determine the viewing angle to Points A and B using the light line values of the linear regression at Points A and B and the RTT eyepiece angle (Θ_{eye}). These equations assume the recording is calibrated to 150 uA and run at 75 uA.

$$\Theta_A = \Theta_{eye} + (LL_A (0.7/40)) \quad (4)$$

$$\Theta_B = \Theta_{eye} + (LL_B (0.7/40)) \quad (5)$$

(7) Find the linear regression angle from the following equation based on the glide slope distance offset from the runway centerline (d_{off}) and the glide slope distance to threshold parallel to the runway (d_o).

$$\Theta_{lin} = \tan^{-1} \left\{ \frac{\sqrt{d_{off}^2 + [d_o + 24304]^2} [\tan \Theta_A] - \sqrt{d_{off}^2 + [d_o + 3500]^2} [\tan \Theta_B]}{20804} \right\} \quad (6)$$

(8) Determine the distance to move the RTT along the line between the antenna base and the runway threshold centerline, accounting for a terrain slope (s).

$$X = \sqrt{d_{off}^2 + (d_o + 3500)^2} \left[1 - \frac{\tan \Theta_B}{\tan \Theta_{lin}} \right] \left[\frac{\sin \Theta_{lin}}{\sin |\Theta_{lin} - s|} \right] \quad (7)$$

The first factor of Equation (7) is a reference distance for the site we are checking. The second factor relates the shift of the new RTT position based on the relationship between the angle at which we view the glide path at Point B and the linear regression angle. The third factor relates the effect of terrain slope to the new RTT position. If X is negative, move the RTT toward the antenna base. If X is positive, move the RTT toward the runway threshold centerline.

(9) Perform another RTT structure run recording the differential trace. The slope of the trace should now be more parallel to the recording centerline

than the trace recorded from the initial RTT position. The linear regression angle will be closer to the average angle as well. The representation of structure on this run will provide a truer indication of the glide path performance.

c. There are three primary assumptions to make in this procedure. First, assume the RTT is aligned between the antenna base and Point B rather than between the antenna base and the threshold centerline. This causes less than 0.01° error in the Point B viewing angle and a negligible change in the viewing angle for Point A. However, a five to seven foot error is incurred for most glide slope sites in the optimum RTT placement. Another assumption is the RTT viewing angles, the average angle, and the linear regression angle pass through the same apparent origin. For the initial RTT position, the apparent origin is the antenna base. The third assumption is the RTT will be repositioned at the same height above ground as at the initial position. Appendix III discusses in detail the inaccuracies associated with these assumptions.

1-4. Examples of RTT Repositioning. Efforts to fully investigate the validity of the procedure have been hampered in recent months by aircraft scheduling and weather. As a result, tests of the procedure at Lajes Field, MacDill AFB, Williams AFB, and Laughlin AFB have had to be dropped or only partially completed. Only two tests of the procedure have been performed to date, one at Myrtle Beach AFB and the other at Duke Field. Appendix IV presents a complete analysis of these tests. A summary of these test results are presented below.

a. The procedure was first tested on the Runway 35 glide slope facility at Myrtle Beach AFB in early February 1982. Structure runs were conducted with the RTT positioned at the standard initial position. Time constraints did not allow calculations to be made before the RTT was moved. The RTT was moved 50 feet forward to investigate the results from a different position. The procedure calculations made from both RTT positions indicate the same location for optimum RTT placement. The procedure indicated both positions were too far forward from the optimum location. Unfortunately, the RTT could not be set up at this optimum location to examine the improvement in the glide path structure recordings. The linear regression angle and average angle were worse at the second position than those from the first position. This agrees with the theory presented in my procedure and indicates the procedure is valid.

b. The second test occurred in March 1982 on the Runway 18 glide slope facility at Duke Field (Eglin AFB Auxilliary Field 3). Structure runs were made from the standard initial position and the calculations were used on-site to determine the new position. However, the calculations were erroneously performed resulting in positioning the RTT 40 feet forward instead of 66 feet in back of the initial position. The structure runs from the second position appear better than those from the first position, even though the RTT was moved the wrong direction. Because the RTT is much closer to the threshold and Point B, all data observed between these points appear at a higher viewing angle and effectively cancels the actual fly-down indication near threshold caused by antenna offset. On the other hand, both the linear regression and average angles improved at the second position, which theoretically should not have occurred. This may indicate the procedure is quite sensitive to the data, and therefore may not always provide an exact optimum location for the RTT. Values from the two positions show different optimum locations, although both positions show the RTT is too far forward. While the numerical values for the optimum location do not agree between the two positions, they do indicate the correct direction to move the RTT. This means the procedure will at least improve the position of the RTT, if not always relocate it at an optimum position.

2. CONCLUSIONS AND RECOMMENDATIONS

2-1. Conclusions:

a. Although there is a very limited experience with this procedure, it appears the procedure is a valid method for improving the RTT position. In some cases, the procedure appears to indicate the optimum location for viewing glide path performance.

b. As indicated during the Duke Field test, the RTT position has a definite effect on the recorded structure, particularly when near the threshold. When in Zones 1 and 2, the effect of RTT placement is not as evident.

c. The procedure appears to be sensitive to the data used in the linear regression. It may be the procedure cannot always indicate an exact optimum location for the position, although it will improve the position.

d. As the RTT position is improved, the linear regression angle and the average angle converge. This implies that once an optimum RTT location is established for a given glide slope site, the normal analysis methods in AFM 55-8 may be used and will produce the same results as linear regression analysis.

2-2. Recommendations:

a. The 1866 Facility Checking Squadron should continue to apply this procedure during all glide slope facility evaluations. As a sufficient data base is built, a more definite indication of the exact capabilities and limitations of this procedure can be derived.

b. Based on the present knowledge of the procedure, I recommend it be used only when commissioning new Category II facilities or when examining glide slope facilities with a history of poor or marginal performance.

APPENDIX I

LINEAR REGRESSION ANALYSIS OF GLIDE SLOPE STRUCTURE

1. Present Method of Glide Slope Structure Analysis:

a. The TRACALS evaluation of a glide slope facility is concerned with the investigation of the glide path performance in the installed environment. Flight inspection of glide slope facilities includes measurement of the facility structure, defined in AFM 55-8 as "an accurate measurement of the magnitude of aberrations (roughness, scalloping, and bends) of the path from the actual path angle and the graphical average path." The structure is measured in Zones 1, 2, and 3 which are shown in Figure I-1. In Zone 1, the aircraft's distance from the RTT makes it difficult to accurately track the aircraft. The differential trace in Zone 1 usually shows little or no structure because the effect of aircraft movement at those distances is less significant. Use of structure data in Zone 3 is suspect because information there is subject to tracking errors by the RTT operator from too much aircraft movement, and parallax errors caused by being offset from the runway centerline. The data collected in Zone 2 is used for most glide slope analysis because it is far enough away to minimize tracking errors by the RTT operator and close enough to depict any glide path anomalies. Zone 2 is also usually the critical sector of the aircraft descent, where transition from instrument to visual approach is accomplished or missed approach procedures are implemented.

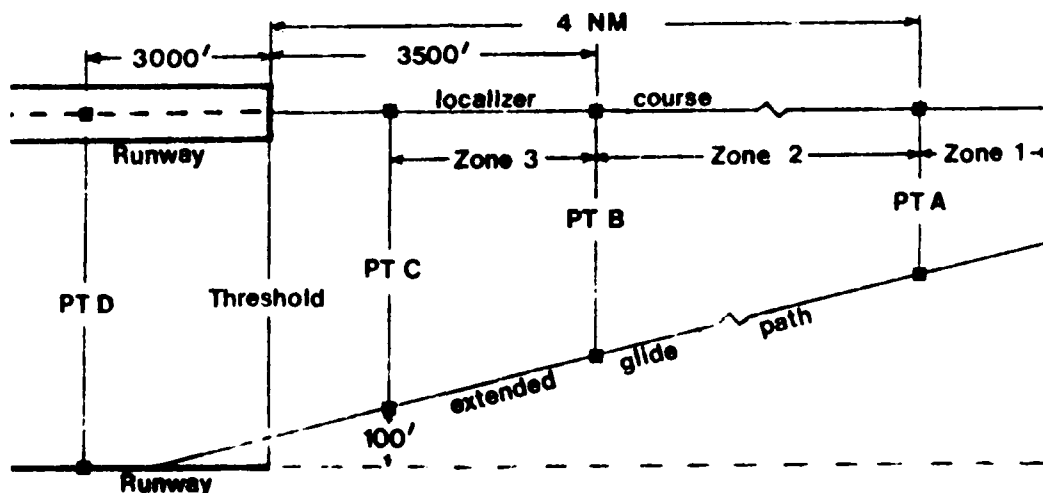


Figure I-1
ILS Reference Points and Zones

b. A sample aircraft structure recording is shown in Figure I-2. The structure information of the glide path is depicted by the differential trace. When distance marks are available on the recording, they can be converted to nautical miles from the glide slope facility or point abeam the glide slope facility on the runway centerline. Whether or not distance marks are available, the recording timing lines can be used. Using timing lines, the RTT run is sampled every two seconds between Points A and B. The panel operator determines the locations of Points A and B on the recording. The difference between the recording centerline (determined by the RTT eyepiece angle) and the trace is measured in light lines or uA. Light line values on the 150 Hz side of the centerline are read as positive values. Light line values on the 90 Hz side of the centerline are read

as negative values. This is due to the method in which the differential trace is developed. The difference represents the angular difference between the RTT eyepiece angle and the differential trace. A further explanation of RTT operation is presented in Attachment 1.

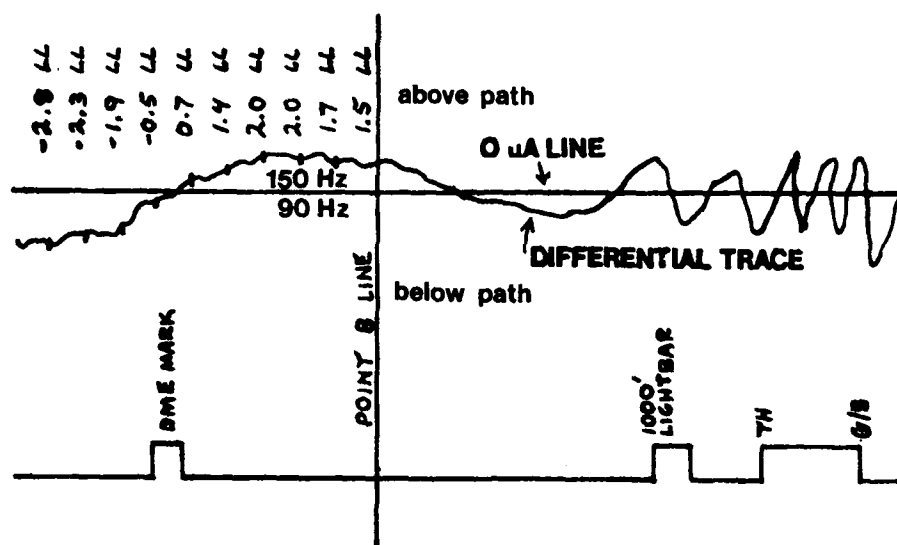


Figure I-2
Sample Aircraft Structure Recording

c. The actual, or average, angle defined in AFM 55-8 is measured in Zone 2. The average angle is the algebraic sum of the RTT eyepiece angle and the average angular difference between the RTT eyepiece angle and the differential trace. Mathematically, this can be stated as follows.

$$\Theta_{\text{avg}} = \Theta_{\text{RTT}} + \bar{X} \quad (1)$$

where Θ_{avg} = Average angle in degrees
 Θ_{RTT} = RTT eyepiece angle in degrees
 \bar{X} = Average difference between the differential trace and the centerline in degrees

\bar{X} is defined as follows.

$$\bar{X} = \left(\frac{1}{n} \right) \sum_{i=1}^n |LL_i| \frac{0.7}{40} \quad (2)$$

where (LL_i) = Light line value of the difference at each sample point i.

The factor (0.7/150) assumes a nominal path width of 0.7° set into the RTT and a recording run calibrated to 150 uA and run at 75 uA.

d. A sample structure run showing the average angle is presented in Figure I-3. Zone 2 structure is measured as the maximum excursion of the actual recorded data from the average angle. In Figure I-3, the maximum structure reading is shown as -2.9 light lines, or about 11 uA below path. If we consider the average angle as a model of the actual glide path, then the elevation (Y) of a point on the glide path above the RTT eyepiece elevation can be found at a distance (X) from the RTT by the equation $Y = X \tan(\Theta_{avg})$.

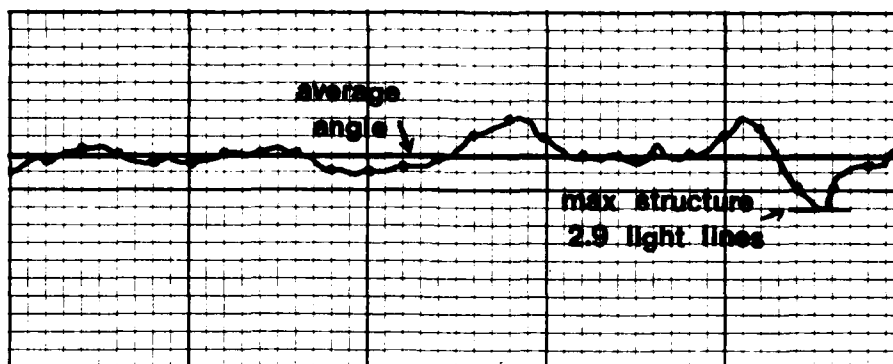


Figure I-3
Average Angle Structure Analysis

2. Linear Regression of Glide Slope Structure Data. Because the glide slope theoretically radiates in a straight line (in the first null of the SBO radiation pattern), the glide slope may be modeled with a linear equation of the form $Y = BX + A$, where A and B are constants. We can find the best fit straight line to our collection of sample points by performing a linear regression using the method of least squares. The constants A and B are then calculated from the following equations.

For (x_i, y_i) , $i = 1, \dots, n$

$$B = \frac{(\sum x_i y_i) - \frac{(\sum x_i)(\sum y_i)}{n}}{(\sum x_i^2) - \frac{(\sum x_i)^2}{n}} \quad (3)$$

$$A = \frac{\sum y_i}{n} - B \left(\frac{\sum x_i}{n} \right) \quad (4)$$

Such a linear regression would appear on the flight recording as shown in Figure I-4.

3. Comparison of Average Angle Versus Linear Regression:

a. The advantage of using the average angle is its simplicity. It is convenient to

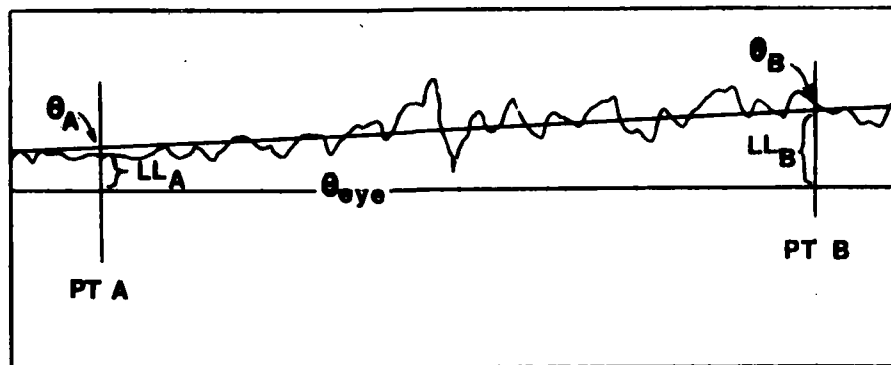


Figure I-4
Linear Regression of Flight Data

use and requires no sophisticated analysis for its derivation. The calculations can be performed quickly by the panel operator. The problem with the average angle is it does not account for any trend of the angle change. It only accounts for the average, and does not show an increasing or decreasing trend in the recorded data, as shown in Figure I-5. Additionally, the trend of the data cannot be based entirely on glide path anomalies, but may also be dependant on the RTT position. The fact that the average angle must pass through the RTT eyepiece makes it dependant on the RTT position. If the RTT is positioned below the extended glide path, the average angle will generally be higher. Conversely, if the RTT is positioned above the extended glide path, the average angle will generally be lower. This was demonstrated in eleven TRACALS evaluations on glide slope facilities conducted in the past three years. The results of these evaluations show the average angle does not allow total separation of the RTT position effects from the true glide path anomalies, and therefore may provide questionable information about the glide path performance. There is no way to tell if an RTT is optimally located from the data provided by the average angle.

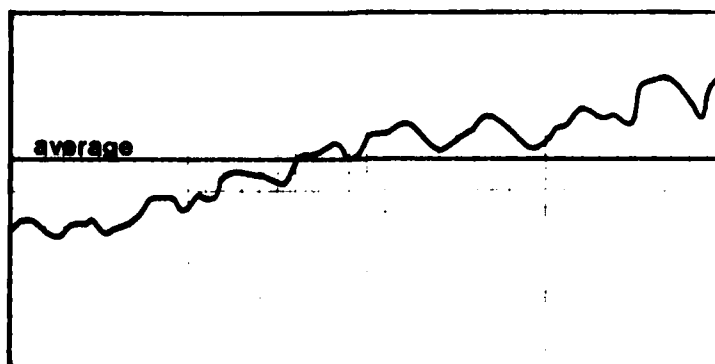


Figure I-5
Inability of Average to Show Data Trend

b. Linear regression analysis is very useful because many different topics can be investigated by its use. The major advantage of linear regression is its ability to depict the trends in the structure data.

(1) The glide path in Zone 2 can be viewed as a straight line in space in accordance with the glide slope theory of linear radiation. If a set of coordinate axes and a reference point are provided, an equation can be developed for the line. Regardless of how the line is viewed, the line is still located in the same position relative to the reference point and coordinate axes. If we assume the glide path has no bends in Zone 2, then the trend depicted by the linear equation gives an indication of the RTT position relative to the extended glide path. This application is based on data collected during the two TRACALS evaluations at Wright-Patterson AFB.

(2) Figure I-6 shows a diagram explaining the effect of RTT position on recorded structure data and the RTT position relative to the extended glide path. (RTT placement also has a slight but negligible effect on the observed glide path width and angle when measured in level runs, as explained in Attachment 3). A linear regression whose slope tends toward the 90 Hz side of the recording as the aircraft approaches threshold indicates the perceived glide angle is gradually decreasing, as shown in Figure I-6a. Assuming the glide path is straight, the perceived decrease in the glide angle implies the RTT eyepiece is above the extended glide path. Likewise, a linear regression whose slope tends toward the 150 Hz side of the recording as the aircraft approaches threshold indicates the perceived glide angle is gradually increasing, as shown in Figure I-6b. This implies the RTT is below the extended glide path.

(3) This analysis indicates the more horizontal the slope of the linear regression, the better the RTT position and the truer indication of glide path performance. The effect of an optimum RTT position and its relation to the extended glide path is shown in Figure I-6c. The ideal situation is shown in Figure I-6d, where the RTT is positioned on the extended glide path with the eyepiece at the true glide angle. Analysis of the glide path structure recordings with linear regression can be used to find the optimum RTT location at glide slope sites without permanent RTT stands, or at unusually configured glide slope sites, such as the once-operational waveguide facility at Malstrom AFB.

(4) Data collected at Wright-Patterson AFB demonstrated the average angles at various RTT locations had a greater dispersion than the angles found by linear regression at those RTT locations. This data is summarized in Attachments 5 and 6. The nature of a linear regression makes it relatively independent from the location of the RTT since the extension of the equation back to the origin will not pass through the RTT eyepiece except for the specific case shown in Figure I-6d. Because of this and the fact that it follows the trend of the data, linear regression provides a true indication of the actual glide angle. The true glide angle of the facility is related to the slope of the linear regression equation, namely (B). If the collection of sample points is converted to a series of coordinate points in space with both units in feet, then the true glide angle would simply be arctangent (B). Linear regression can be used to determine other glide slope parameters as explained in Attachments 2 and 4.

4. Use of the Linear Regression by Flight Inspection and TRACALS Evaluation Personnel:

a. There are two hand-held calculators presently in the Air Force inventory used by flight inspection as well as TRACALS evaluation personnel to perform linear regression and average angle calculations during flight inspections or TRACALS evaluations. These two calculators are the Hewlett-Packard Model HP-25, NSN 7420 PHP25, and the Texas Instruments Model TI-59, NSN 7420 01 054 4382. Procedures for using the HP-25 calculator to solve linear regression and average angle are presented in Attachment 8. A program written for the TI-59 calculator to compute linear regression, new RTT placement, and average angle is presented in Attachment 9. A program is also

presented in Attachment 10, written in Applesoft BASIC for an Apple computer. In addition, other programmable calculators can be used to perform linear regression and average angle calculations.

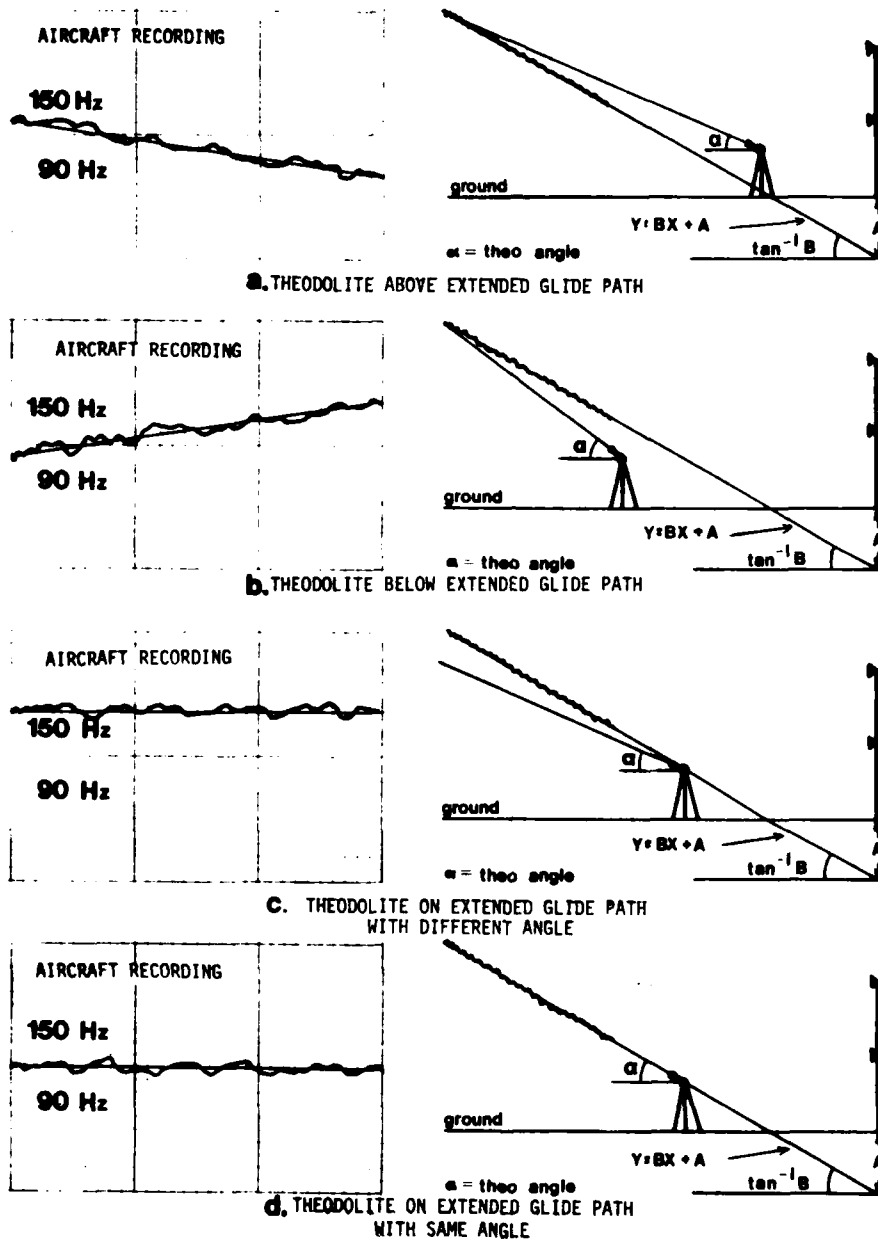


Figure I-6
Effect of RTT Placement on Recorded Glide Path Structure

b. The primary end product for the flight inspection personnel is a line on the recording used to measure the structure and depict the glide angle. Timely computation during a flight inspection is essential to save funds and resources. As an added feature

of linear regression, the units of the coordinate axes do not have to be equivalent. Data points can be read in coordinates of nautical miles and light lines or in the readily available coordinates of seconds and light lines to save more time. When using seconds as the X-coordinate, the zero reference should be the glide slope antenna and increase toward Point A. With this reference, Point B will generally occur between 10-20 seconds and Point A will occur between 60-90 seconds, depending on the speed of the aircraft. It is important to use the same reference on the recording as the data points when drawing the linear regression.

APPENDIX II

DERIVATION OF THE EQUATION FOR RTT REPOSITIONING BY LINEAR REGRESSION ANALYSIS OF GLIDE SLOPE STRUCTURE

1. General. This appendix presents a step by step development of the equation for repositioning an RTT using linear regression analysis of the glide slope structure. It also includes the reasoning behind the assumptions in the derivation and a listing of the variables used.

2. Thought Process for Position Improvement:

a. In order to correct our RTT position for optimum viewing of the glide path, we must first collect an initial set of RTT structure data and obtain a linear regression. The linear regression on the flight recording represents a linear regression in space of the glide path. The linear regression in space will have some angle to the horizontal reference plane, which we will call (Θ_{lin}). The ideal place to view this linear regression is a direct end view of the line. In other words, the line would appear as a point, with no parallax errors involved. The only time we would be able to "see" the point view of the linear regression with the RTT eyepiece is to be positioned on the runway centerline at the runway point of intercept (RPI) of the linear regression.

b. Positioning the RTT in such a manner is impractical for obvious reasons of safety, so we must position the RTT offset from the runway centerline. Let us limit ourselves to position the RTT somewhere along a line between the antenna base and the runway threshold centerline. This will coincide with existing methods and also limit our movement from the initial RTT position we used to obtain the linear regression. Our initial RTT position was such that we backsighted the antenna base at minus the commissioned or desired angle. Data collected from several TRACALS Evaluations support the premise that the linear regression angle (Θ_{lin}) will not differ much from the average angle, nor will either of these differ much from the RTT eyepiece angle if it's relatively close to being correct. Consequently, we can assume negligible change in the initial RTT position no matter which of the three angles is used to backsight to the antenna base. Therefore, we can state the initial RTT position is sufficient for acquiring the linear regression.

c. The advantage in having a sufficient initial RTT position is we can now have a reference for all our calculations. This reference is the antenna base, which appears as our initial origin of the glide slope signal. Because the linear regression does not pass through the RTT eyepiece except for one specific case, the linear regression will usually show a new apparent origin of the signal, which may either be behind or in front of our initial origin. Our desire is to reposition the RTT to align the eyepiece to backsight to the new apparent origin.

d. Before we get into the actual derivation of the RTT positioning equation, it is convenient at this point to list the variables used. These appear as follows.

- Θ_{avg} = Average angle of the structure data in degrees
- Θ_{lin} = Angle of the linear regression from the horizontal in degrees
- Θ_{eye} = RTT eyepiece angle in degrees

- Θ_A = Observed elevation angle of the linear regression at Point A in degrees
 Θ_B = Observed elevation angle of the linear regression at Point B in degrees
 s = Slope in terrain from the horizontal in front of the initial origin in degrees
 α = Obtuse angle between the terrain slope and the line defined by the linear regression in degrees
 d_{off} = Offset distance of the antenna base from the runway centerline in feet
 d_o = Distance along the runway centerline from the threshold to the point abeam the antenna base in feet
 d_a = Direct distance from the RTT position to Point A in feet
 d_b = Direct distance from the RTT position to Point B in feet
 D_A = Direct distance from the antenna base to Point A in feet
 D_B = Direct distance from the antenna base to Point B in feet
 D_{theo} = Horizontal distance the RTT is moved along the line between the antenna base and the runway threshold centerline in feet
 LL_A = Light line value of the linear regression at Point A
 LL_B = Light line value of the linear regression at Point B
 X = Distance along the terrain surface the RTT is moved from the initial position to the new position in feet.

e. Let's now look at the geometry involved in my calculations. For the initial RTT position, the geometry appears as shown in Figure II-1.

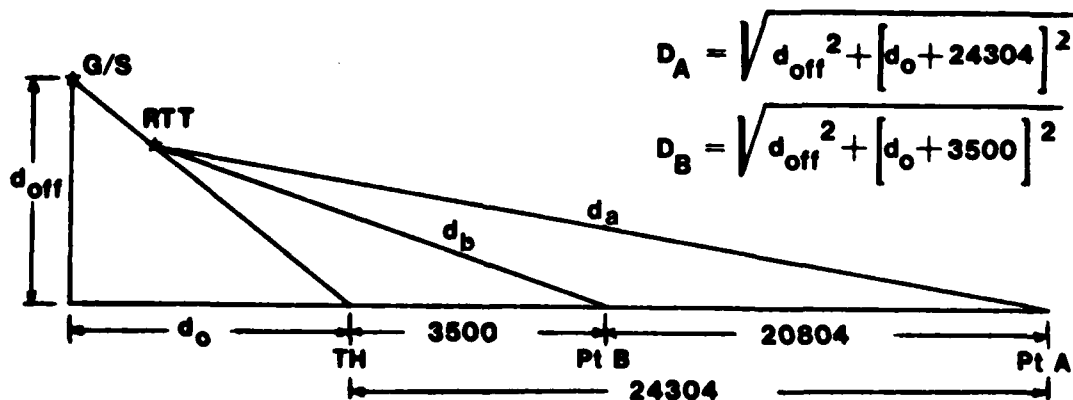


Figure II-1
RTT Position Geometry

We can see the trigonometry involved with determining all results from our initial RTT position will get somewhat difficult since the location is not in line with the antenna base and either of the points we are interested in. Therefore, I will assume (d_a) and (d_b) will not appreciably change if I envision the RTT as being placed along the line between the antenna base and Point B. This will simplify the mathematical development and the final equation later on. Figure III-1 in Appendix III shows the error in feet incurred for various combinations of (d_{off}) and (d_o) because of this assumption. Generally, we could expect about six to seven feet error in the new RTT position. Without actually moving the RTT to this new alignment, let's pursue the problem as if it were aligned between the antenna base and Point B. Our geometry for this situation would now appear as shown in Figure II-2.

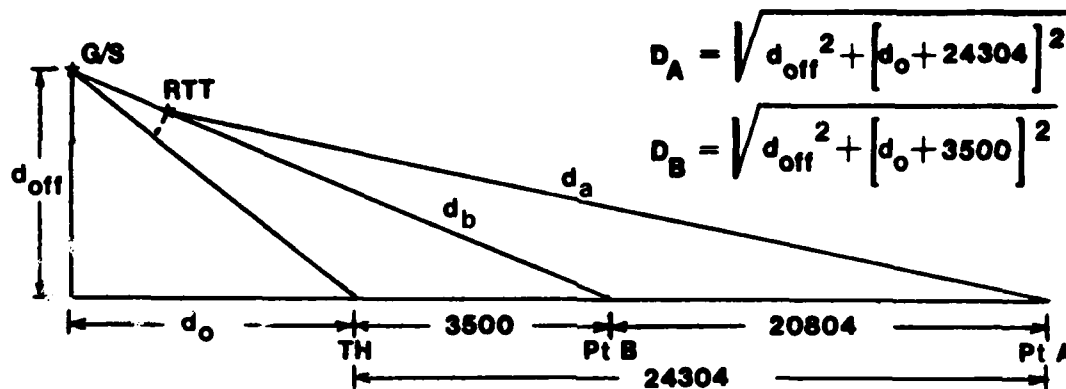


Figure II-2
Revision to RTT Position Geometry for Mathematical Simplification

f. Let's suppose the elevation angle at which we view the glide path at Point A will not noticeably change when we envision the RTT aligned to Point B, because (d_a) is large compared to the distance the RTT is moved. The nominal change in (d_a) from moving the RTT is less than 0.043%. The elevation angle at which we view the glide path at Point B is more dependant on the RTT position. The nominal change in (d_b) from moving the RTT is about 0.352%. Although this error is not particularly significant, let's move the RTT such that the eyepiece angle required to observe the glide path at Point B is the linear regression angle (Θ_{lin}). This will allow structure at Point B (which is where the structure tolerances become critical) to be observed as if we could view the glide path at the RPI of the linear regression. Remember, the angle at which we view Point A will not appreciably change when moving the RTT (if we move the RTT 150 feet toward the threshold, for example, the angle to view the glide path at Point A will change less than 0.50%). The end result is to position the RTT along the line between the antenna base and the runway threshold centerline so the linear regression data on the flight recording is seen at a constant angle. In other words, the linear regression on the flight recording is parallel to the differential trace centerline (Θ_{eye}). If (Θ_{lin}) is greater than (Θ_{eye}), we must move away from the antenna base to increase our viewing angle to the glide path at Point B. Conversely, if (Θ_{lin}) is less than (Θ_{eye}), we must move closer to the antenna base to lower our viewing angle to the glide path at Point B.

3. Derivation:

a. Once we have the linear regression, we can find the light line values of the linear regression at Points A and B. We can use these values to find our viewing angles

to Points A and B from the following equations.

$$\Theta_A = \Theta_{eye} + (LL_A (0.7/40)) \quad (1a)$$

$$\Theta_B = \Theta_{eye} + (LL_B (0.7/40)) \quad (1b)$$

If we drew our known information on the flight recording, it would appear something like Figure II-3. We can now see how the RTT will be moved by looking at the values for (Θ_A) and (Θ_B) . When (Θ_A) is greater than (Θ_B) , the RTT is too close to the antenna base; conversely, when (Θ_A) is less than (Θ_B) , the RTT is too far away from the antenna base.

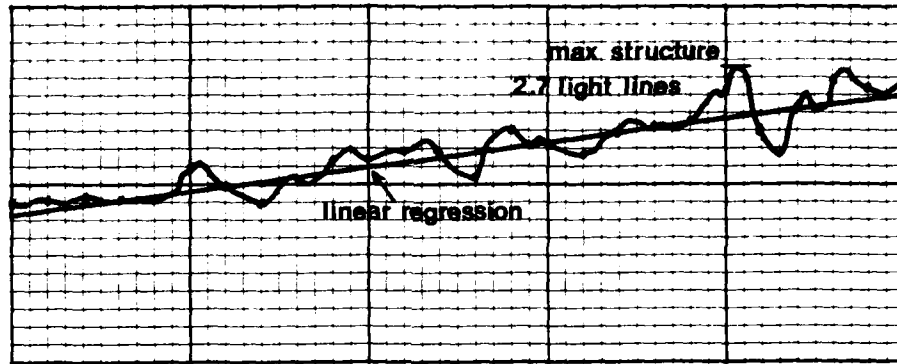


Figure II-3
RTT Structure Run Showing Linear Regression

b. Remember an assumption I made stating the RTT position is essentially unaffected whether we use (Θ_{lin}) , (Θ_{eye}) , or (Θ_{avg}) to backsight to the antenna base. Therefore, (Θ_A) and (Θ_B) also originate from the antenna base as well (for the initial RTT position). We can then make an intermediate step to calculate the heights in space of the linear regression by using the distances from the antenna base to Points A and B (D_A and D_B , respectively) in the following equations.

$$H_A = D_A \tan(\Theta_A) \quad (2a)$$

$$H_B = D_B \tan(\Theta_B) \quad (2b)$$

c. We can use the heights at Points A and B to find the elevation angle of the linear regression relative to the horizontal. The geometry for this calculation is shown in Figure II-4. With a simple trigonometric identity, we arrive at (Θ_{lin}) by the following equation.

$$\Theta_{lin} = \tan^{-1} \left[\frac{H_A - H_B}{20804} \right] \quad (3)$$

Now let's substitute Equations (2a) and (2b) into (3), and also have (D_A) and (D_B) in terms of (d_{off}) and (d_o) as depicted in Figure II-1. Our final equation for (Θ_{lin}) is as follows.

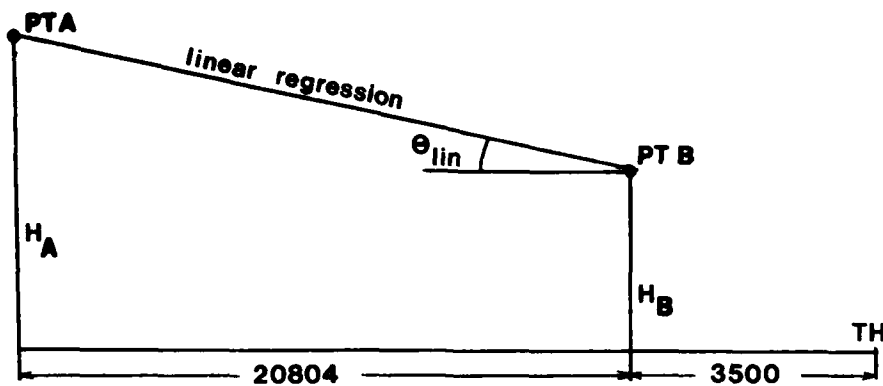


Figure II-4
Geometry for Determining Linear Regression Elevation Angle

$$\theta_{lin} = \tan^{-1} \left\{ \frac{\sqrt{d_{off}^2 + [d_o + 24304]^2} [\tan \theta_A] - \sqrt{d_{off}^2 + [d_o + 3500]^2} [\tan \theta_B]}{20804} \right\} \quad (4)$$

d. We want to reposition the RTT to view Point B at (θ_{lin}) . Since (H_B) should remain unchanged, then moving the RTT will appear to align the eyepiece to some new apparent origin. The horizontal distance from Point B (at the same elevation as our initial origin, the antenna base) to the new apparent origin (D_B') is found with Equation (5).

$$D_B' = \frac{H_B}{\tan \theta_{lin}} \quad (5)$$

e. I will now make an assumption concerning the height of the RTT. Assume the RTT will be repositioned at the same height above the ground as at the initial position. This is a valid assumption because the same RTT operator will be at the site moving the RTT. It is logical to assume he will set up the RTT at the same eyepiece height for his own comfort every time. Let us also assume the terrain is flat. This means the new apparent origin is at the same elevation as the initial origin. If we make these assumptions, the distance we should move the RTT is simply the difference between (D_B) and (D_B') , shown in Equation (6).

$$D_{theo} = D_B - D_B' \quad (6)$$

Because we have (H_B) in terms of (D_B) in Equation (2b), let's substitute (2b) into (5). Then we now can substitute Equation (5) into (6) for (D_B') , and have (D_{theo}) in terms of (D_B) .

$$D_{\text{theo}} = D_B - \left[\frac{D_B \tan \theta_B}{\tan \theta_{\text{lin}}} \right]$$

$$D_{\text{theo}} = D_B \left[1 - \frac{\tan \theta_B}{\tan \theta_{\text{lin}}} \right] \quad (7)$$

If we put (D_B) in terms of the more easily known distances (d_{off}) and (d_o) from Figure II-1, then our equation for RTT positioning with flat terrain in front of the antenna base is shown in Equation (8).

$$D_{\text{theo}} = \sqrt{d_{\text{off}}^2 + (d_o + 3500)^2} \left[1 - \frac{\tan \theta_B}{\tan \theta_{\text{lin}}} \right] \quad (8)$$

f. In many cases, we will not have flat terrain in front of the antenna base. We should therefore adjust Equation (8) to reflect a general case for terrain slope. Figure II-5 illustrates the geometry used to account for terrain slope. In this figure, the slope is a negative value. A similar geometric relationship can be drawn for a positive slope and for negative values of (D_{theo}). All angles and sides will have the same relationship with each other.

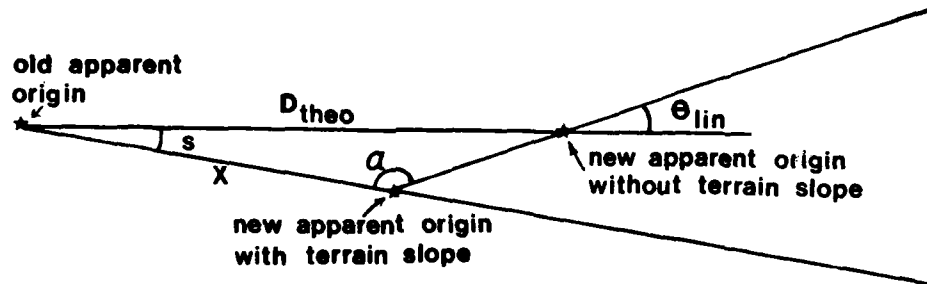


Figure II-5
Geometry for Incorporating Terrain Slope Into RTT Repositioning

Having made the assumption the RTT eyepiece will be repositioned at the same height above the terrain, then the distance to move the RTT on sloping terrain is X from Figure II-5. We can find an equation for X using the Law of Sines.

$$\frac{\sin a}{D_{\text{theo}}} = \frac{\sin \theta_{\text{lin}}}{X}$$

$$X \sin a = D_{\text{theo}} \sin \theta_{\text{lin}}$$

$$X = D_{\text{theo}} \left[\frac{\sin \theta_{\text{lin}}}{\sin a} \right] \quad (9)$$

The angle (a) needs to be expressed in some other terms. Let's put it in terms of (θ_{lin}) and the terrain slope (s), as shown in Equation (10).

$$a = 180 - \theta_{\text{lin}} + s \quad (10)$$

You will notice s is a positive term in (10) because we consider it negative in Figure II-5. We can now reduce (10) to (11) through the following process.

$$\begin{aligned} a &= 180 - \theta_{\text{lin}} + s \\ \sin a &= \sin (180 - \theta_{\text{lin}} + s) \\ \sin a &= \sin (180 - (\theta_{\text{lin}} - s)) \\ \sin a &= \sin (\theta_{\text{lin}} - s) \end{aligned} \quad (11)$$

If we substitute (11) into (9) for ($\sin a$), we get the following equation.

$$X = D_{\text{theo}} \left[\frac{\sin \theta_{\text{lin}}}{\sin (\theta_{\text{lin}} - s)} \right] \quad (12)$$

g. Our final step is to substitute Equation (8) into (12) for (D_{theo}). We now have an equation for (X) to reposition the RTT with a slope in the terrain.

$$X = \sqrt{d_{\text{off}}^2 + (d_o + 3500)^2} \left[1 - \frac{\tan \theta_B}{\tan \theta_{\text{lin}}} \right] \left[\frac{\sin \theta_{\text{lin}}}{\sin (\theta_{\text{lin}} - s)} \right] \quad (13)$$

Although this is a horrendous looking equation, the three terms represent specific items about the new RTT position. The first factor is a reference distance for the site we are checking. The second factor relates the shift of the new RTT position based on the relationship between the angle at which we view the glide path at Point B and the linear regression angle. The third factor relates the effect of terrain slope to the new RTT position.

APPENDIX III

ACCURACIES INVOLVED IN USING LINEAR REGRESSION ANALYSIS FOR RTT REPOSITIONING

1. General:

a. The technique which we use to measure glide path structure, that of tracking the aircraft flight with a ground based theodolite, has certain absolute errors which we are constrained by. Fortunately, these errors are small, so a high degree of accuracy can be achieved. There are three primary areas limiting the accuracy of our measurement technique.

(1) The majority of theodolites used in glide slope flight inspection have a calibrated accuracy of 0.01° . Generally, a qualified theodolite operator will be able to track the aircraft flight within 0.01° of its actual position.

(2) The RTT transmitter design also provides a small inaccuracy. The calibration procedure and meter face on most transmitters generally produce enough variance to cause a 2-3 uA error in the transmitted signal. Using normal aircraft receiver calibration, this will induce about 0.01° error in the differential trace.

(3) The recording light lines are physically about 0.1 inches apart. It is generally possible to read the differential trace to within 0.5 light lines. Using normal receiver calibration, this corresponds to less than 0.01° error in the differential trace.

(4) The cumulative error of measuring glide path angles resulting from our measurement technique is about 0.03° . This is comparable to the accuracy achieved using an automated flight inspection system.

b. In the process of developing my procedure for optimum repositioning of an RTT based on linear regression analysis of glide slope structure, I made several assumptions to help simplify the derivation. Whenever most simplifying assumptions are made, there is usually some inherent loss of accuracy associated with the assumptions. Some of the simpler assumptions I made are already discussed in Appendix II. I will now examine the more complex assumptions I made in my derivation and their associated accuracies.

2. Assuming RTT Alignment to Point B Instead of Threshold:

a. One of my major assumptions was we could envision the RTT as being placed along the line between the antenna base and Point B, to simplify the mathematics. Because we are backsighting our initial RTT position to the antenna base, the RTT will be the same distance from the antenna base when realigned to Point B. However, this will change the RTT's distance to Point B, which affects the angle at which we view the linear regression and glide path at Point B.

b. For small angles such as 3.00° or less, the tangent of the angle is simply the value of the angle in radians. Since the tangent is proportional to the distance from Point B, a change in the distance will cause a proportionate change in the angle. Figure III-1 shows the change in distance from the RTT to Point B assuming alignment to Point B. This is done for various combinations of the glide slope offset distance (d_{off}) and distance to threshold (d_t). For example, let's use a distance to threshold of 1000 feet and an offset distance of 500 feet. Figure III-1 shows the distance from the RTT to Point B

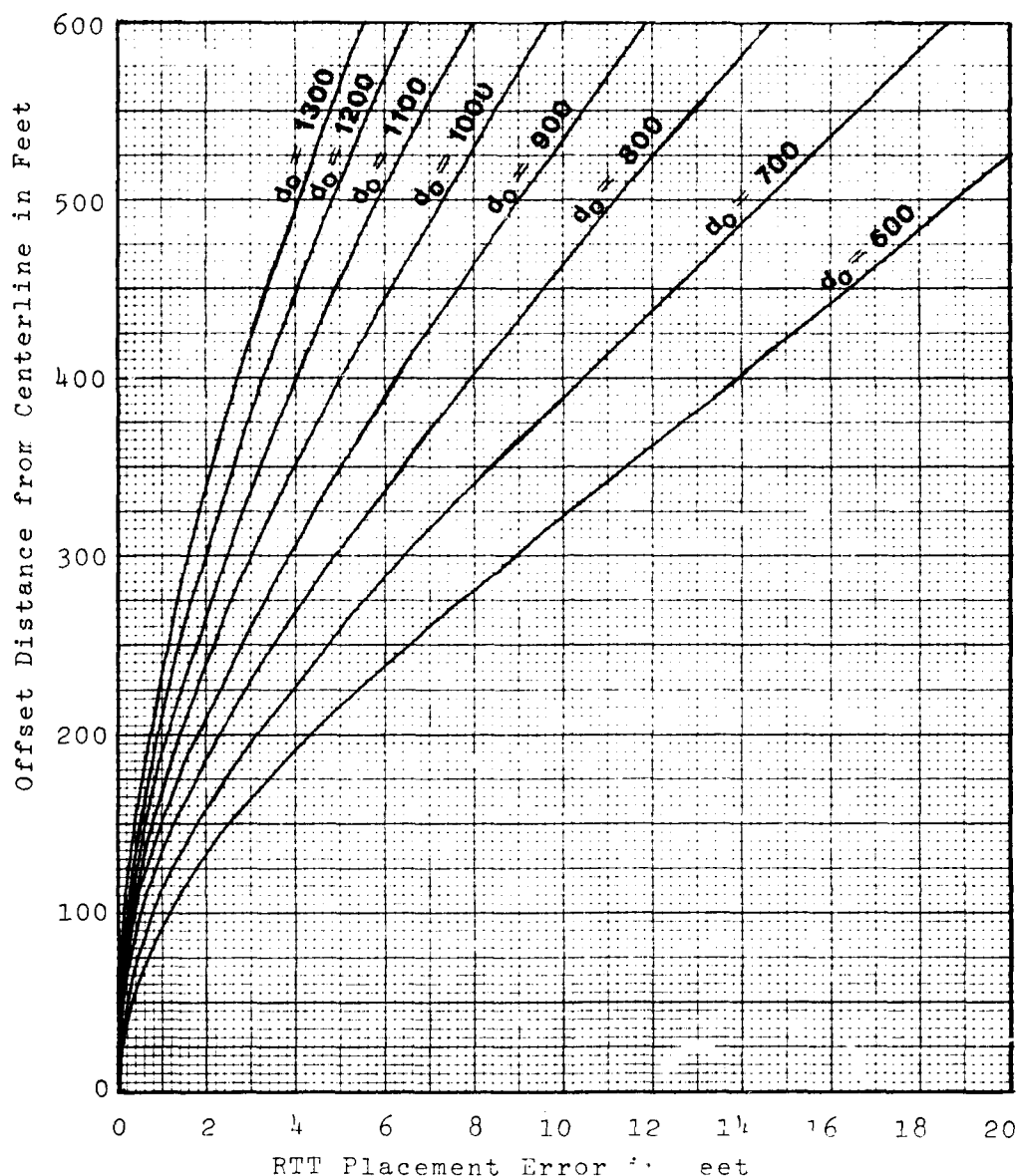


Figure III-1
RTT Placement Error Assuming Placement Between Site and Point B
Versus Site and Threshold

will be 7.3 feet different (shorter) when assuming alignment to Point B rather than the actual alignment to threshold. The RTT distance from the antenna base used in Figure III-1 is 115 feet, corresponding to an angle of about 2.75° .

c. Figure III-1 shows that as the ratio of (d_o) to (d_{off}) decreases, the change in distance will increase, and vice versa. The closer the facility is to the lower left corner of Figure III-1, the less inaccuracy is incurred in my derivation by assuming RTT alignment to Point B. In the example above ($d_o = 1000$, $d_{off} = 500$), the RTT distance to Point B is 4412.7 feet. The 7.3 feet from Figure III-1 represents an error of 0.165% in distance, or an error of less than 0.01° in the Point B viewing angle. These errors are

within the limits of our measurement techniques; therefore, I can envision the RTT as being aligned to Point B for simplification of the mathematics in my derivation.

3. Absolute Error of Viewing the Linear Regression in Space From An Offset Position:

a. As I stated in Appendix II, the ideal place to view the linear regression in space is from a direct end view of the line. This means the RTT is located on the runway centerline at the RPI of the linear regression. Because we cannot do this, we incur some error by moving away from the point view. The amount of error is dependant primarily on (d_{off}) and to a lesser degree on (d_o).

b. Figure III-2 depicts the absolute accuracy of viewing a perfectly straight line from various RTT locations. The graphs were developed by sampling 20 points from a perfect linear regression at 3.00° (coefficient of determination is 1) based on various combinations of (d_{off}) and (d_o). The value of 3.00° is used because it will cause the largest amount of inaccuracy when varying (d_o) and (d_{off}). We can see that (d_{off}) has the major effect on the absolute percent of accuracy. Changing (d_o) affects the absolute accuracy very little because the graphs for various values of (d_o) are close together.

c. The results indicate we can expect better than 99.8% accuracy in our measurements for the majority of glide slope sites in existence, even though we have offset the RTT from the ideal viewpoint. This level of accuracy will not appreciably affect the RTT positioning procedure when the RTT is placed in its usual position along a line between the glide slope antenna base and the runway threshold centerline.

4. Assuming All Major Elevation Angles Pass Through the Same Apparent Origin:

a. Early in my derivation, I assumed that the linear regression angle, the average angle, and the eyepiece angle would not differ appreciably from each other and hence appear to pass through the same apparent origin. The position of the origin is related to the tangent of the elevation angle when the RTT is kept at a constant height above the ground. Therefore, we can get an idea of the disparity between angles that will not cause the origin to change by more than five feet. Table III-1 presents this relationship of origin distance from the RTT versus elevation angle. The RTT height for these calculations is 5.5 feet.

b. Table III-1 shows that more change in the apparent origin occurs for a change in elevation angle when the elevation angle is lower. Even at 2.50° , a change of 0.1° in the elevation angle will cause about 5.0 feet change in the apparent origin. This means if the eyepiece angle is 0.1° off from the average or linear regression angles, it appears to originate only 5.0 feet from the origins of the average and linear regression angles. Our ability to measure the aircraft position in space is not accurate enough for a 5.0 feet change in the origin to cause a significant error in my procedure. Thus we can tolerate a dispersion between the eyepiece angle, the linear regression angle, and the average angle of up to 0.1° without introducing an appreciable error in the calculations for a new RTT position.

5. Assuming a Constant RTT Eyepiece Height Above Ground. I made the assumption that when we move our RTT to the new position, it will be set up at the same height above the ground. This appears to be valid because during a given evaluation or flight inspection the same theodolite operator would be tracking the aircraft. However, the operator will probably vary the eyepiece height somewhat due to terrain or other considerations. If we keep the RTT eyepiece angle constant (2.5°), we could vary the

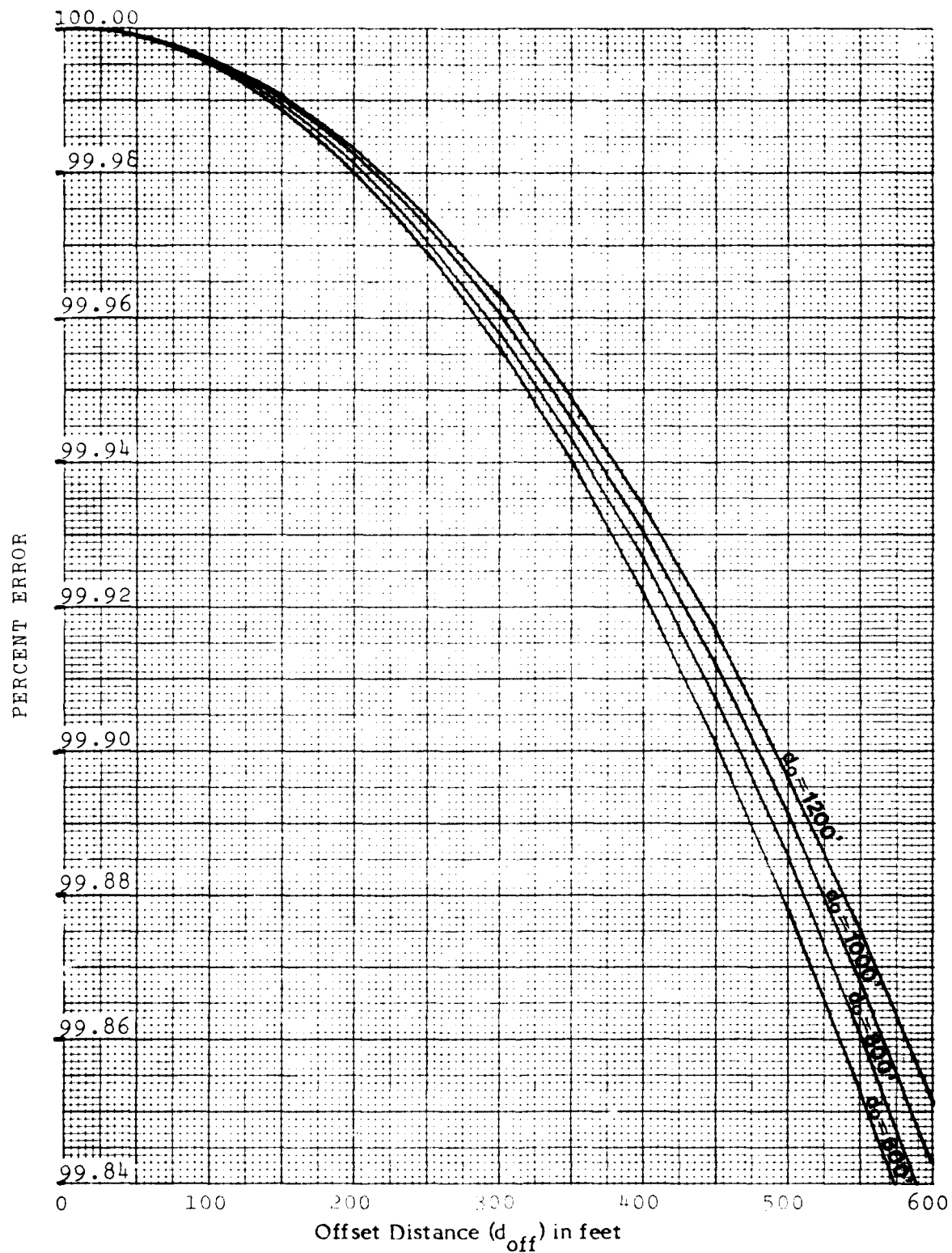


Figure III-2
Absolute Error of Viewing a Linear Regression in Space
From An Offset Position

TABLE III-1
ORIGIN DISTANCE VERSUS ELEVATION ANGLE

ELEVATION ANGLE IN DEGREES	DISTANCE FROM RTT TO ORIGIN IN FEET	CHANGE OF DISTANCE IN FEET
2.45	128.5	
2.50	126.5	2.5
2.55	123.5	2.5
2.60	121.1	2.4
2.65	118.8	2.3
2.70	116.6	2.2
2.75	114.5	2.1
2.80	112.5	2.0
2.85	110.5	2.0
2.90	108.6	1.9
2.95	106.7	1.9
3.00	104.9	1.8
3.05	103.2	1.7

TABLE III-2
DISTANCE TO ORIGIN VERSUS RTT HEIGHT
FOR A CONSTANT ANGLE

EYEPIECE HEIGHT IN FEET	ORIGIN DISTANCE IN FEET	DISTANCE CHANGE IN FEET
6.0	137.4	
5.9	135.1	2.3
5.8	132.8	2.3
5.7	130.6	2.2
5.6	128.3	2.3
5.5	126.0	2.3
5.4	123.7	2.3
5.3	121.4	2.3
5.2	119.1	2.3
5.1	116.8	2.3
5.0	114.5	2.3

eyepiece height and see the change in the distance to the origin for flat terrain. The 2.5° angle will cause the largest change in the distance to the origin. The results of this analysis are summarized in Table III-2 and indicate we could tolerate an eyepiece height change of 0.2 feet (about 2.5 inches) without changing the origin distance more than 5.0 feet. A theodolite operator, while not always setting up the theodolite the same exact height every time, would most likely set his eyepiece height within 2.5 inches of his nominal comfortable value. Variances in eyepiece height from operator to operator will not affect the RTT positioning procedure because the eyepiece is actually referenced to an apparent origin through the eyepiece angle. The operator will still have to move the RTT the same amount whether his eyepiece height is 5.0 feet or 6.0 feet. The limitation to this analysis is the same operator must move and set up the RTT at the new position.

APPENDIX IV

EXAMPLES OF RTT REPOSITIONING

1. General. Opportunities to fully explore the feasibility and accuracy of this procedure have rarely been available during TRACALS evaluations. As a result, I have only been able to perform the procedure at a very limited number of bases. This appendix presents examples showing how the RTT positioning procedure was used during recent TRACALS evaluations.

2. Myrtle Beach AFB, SC SSILS Evaluation. The first full use of the procedure occurred during the Myrtle Beach AFB, SC SSILS evaluation on Runway 35 from 27 January to 18 February 1982. During the course of this commissioning-evaluation, the procedure was attempted. However, because of delays due to weather and aircraft scheduling, a more thorough investigation could not be accomplished.

a. A contour study of the Runway 35 glide slope site and signal forming terrain was performed and is shown in Attachment 11. In addition, the following variables were collected for the procedure.

$$\begin{aligned}d_o &= 1063.55 \text{ feet} \\d_{off} &= 500.66 \text{ feet} \\s &= -0.43^\circ \\ \theta_{eye} &= 3.00^\circ\end{aligned}$$

b. Structure runs were conducted with the RTT at the standard initial position (along the line between the antenna base and the runway threshold centerline such that the eyepiece backsights the antenna base at $(-\theta_{eye})$). Because of time constraints, the positioning calculations could not be performed before the RTT was moved. The evaluation team chief decided to move the RTT 50 feet forward to examine the effect of a different location. After moving the RTT, another series of structure runs was performed. The same pilot and RTT operator were used in both sets of runs. Afterwards, RTT positioning calculations were accomplished on all structure runs using Equations (1a), (1b), (4), and (13) from Appendix II. Graphs of the structure runs used for these calculations are shown in Attachment 12. The results of the calculations are presented in Table IV-1.

c. The Myrtle Beach AFB results support the validity of this procedure. The initial runs in Attachment 12 show the original RTT position was not far from optimum based on the slope of the linear regression. The graphs slope slightly upward from Point A to Point B indicating the RTT is too far forward. The results of the calculations agree and indicate the RTT should be moved back about 66 feet.

d. The RTT was repositioned 50 feet forward. At this position we should expect a greater slope in the linear regression line and perhaps worse structure indications on the recordings. The structure runs after the move show this to be the case. Calculations for the optimum RTT position from these runs indicate the RTT should be moved back about 110 feet. This corresponds (within 6 feet) to the indicated optimum position from the initial set of structure run calculations. Figure III-1 also indicates the calculations will have an error of about 6.6 feet for the Myrtle Beach site. Based on this information, both sets of structure runs indicate the correct position where the RTT should have been moved.

TABLE IV-1
RTT POSITIONING RESULTS AT MYRTLE BEACH AFB, SC

	POINT A VIEWING ANGLE (DEGREES)	POINT B VIEWING ANGLE (DEGREES)	LINEAR REGRESSION ANGLE (DEGREES)	AVERAGE ANGLE (DEGREES)	RTT MOVE (FEET)
INITIAL POSITION					
RUN #1	3.0160	3.0479	3.0057	3.0324	-64.6
RUN #2	3.0041	3.0377	2.9935	3.0211	-68.0
RTT MOVED +50 FEET					
RUN #1	3.0410	3.1020	3.0243	3.0717	-103.6
RUN #2	3.0426	3.1031	3.0260	3.0725	-117.2

3. Duke Field, FL SSILS Evaluation. A special glide slope evaluation was conducted on Runway 18 at Duke Field, FL (Eglin AFB Auxilliary Field 3) from 11-22 March 1982. A portion of this evaluation was dedicated to investigating the RTT positioning procedure.

a. A contour study of the glide slope site and signal forming terrain had been performed during a previous TRACALS evaluation. It is presented in Attachment 11. The following positioning variables were also collected.

$$\begin{aligned}
 d_o &= 1265.0 \text{ feet} \\
 d_{\text{off}} &= 500.0 \text{ feet} \\
 s &= 0.17^\circ \\
 \theta_{\text{eye}} &= 3.00^\circ
 \end{aligned}$$

b. A structure run was performed on each transmitter with the RTT positioned in the normal initial position. Equations (1a), (1b), (4), and (13) from Appendix II were used on-site to calculate values for the new RTT position based on both structure runs. However, an error was made during the calculations resulting in moving the RTT 40 feet forward. Structure runs were then performed on each transmitter from this new position and RTT position values were later calculated based on these runs. The same pilot and RTT operator were used throughout the measurements except for the second run from the new position, which was flown by a different pilot. Graphs of the Duke Field structure runs are shown in Attachment 12. The results of the RTT positioning analysis are presented in Table IV-2.

c. The results in Table IV-2 indicate several discrepancies. The structure in Zone 3 is vastly improved at the new position while the overall structure indications in Zone 2 remain about the same. In addition, the calculations from the two positions give different positions where to move the RTT. The most significant discrepancy is the average and linear regression angles were improved at the second position although the RTT was moved the wrong direction. The two angles are closer to each other and the linear regression shows less slope on the recording than from the initial position.

TABLE IV-2
RTT POSITIONING RESULTS AT DUKE FIELD, FL

	POINT A VIEWING ANGLE (DEGREES)	POINT B VIEWING ANGLE (DEGREES)	LINEAR REGRESSION ANGLE (DEGREES)	AVERAGE ANGLE (DEGREES)	RTT MOVE (FEET)
INITIAL POSITION					
RUN #1	2.9497	2.9981	2.9355	2.9734	-108.7
RUN #2	2.9525	2.9993	2.9388	2.9754	-105.0
RTT MOVED +40 FEET					
RUN #1	2.9663	3.0094	2.9534	2.9879	-96.7
RUN #2	2.9736	3.0078	2.9627	2.9906	-77.2

d. The apparent improvement in Zone 3 structure from the new RTT position can be easily explained because the RTT is grossly misplaced at the new position. The position is much closer to the threshold and Point B; consequently, everything in Zone 3 will appear at a higher viewing angle. The effect is to cancel the original fly-down indication caused by antenna offset and make it appear improved by following the general trend of the linear regression. This is a very good example of the effect of RTT position on the recorded structure data.

e. The individual runs from the new position indicate about 20 feet difference in the calculations for the optimum RTT position. The only significant factor differing from these two runs is a different pilot. Pilot technique should not be an important factor in the procedure, but these results indicate it may play a larger role than expected. Examining the raw data recorded during these runs revealed the differences in reference marks had a slight effect on the resultant differential trace. Normally, one pilot flies the glide slope while the other provides event marks for the recording, looking out the window and marking the 1000 foot light bar, the threshold, and the antenna as the aircraft passes. A pilot providing reference marks with the glide slope on his side of the aircraft will mark with greater accuracy than when the glide slope is on the opposite side of the aircraft, although when the same pilot is used on all runs, the event marks are consistent and no analytical errors are introduced. However, by changing pilots between runs it is possible to change the relative locations of the event marks on the recording. The middle marker trace was recorded on each run, and it can be seen there are some differences in the distance references on the recordings because of the event marks. The actual flight technique differences between pilots have a negligible effect on the recordings because the RTT compensates for the aircraft not being on the glide path. As a result, it appears the differences in RTT indications between the two RTT positions and between the two runs at the new position are probably indicating the procedure is quite sensitive to the data. This may indicate it is not always possible for the procedure to provide an exact optimum location for the RTT.

f. The one positive result from Duke Field is both positions do indicate the correct direction to move the RTT. Averaging the two values from the new position, there is about 60 feet difference in the actual location of the "optimum" RTT location between the two positions used in the test. Assuming the procedure is indeed valid, the actual optimum RTT position probably lies somewhere between these two locations. In any case, the procedure indicates the RTT was placed too far forward at both positions. This means the procedure will at least improve the position of the RTT, if not relocate it at an optimum location.

TECH MEMO

TITLE: THE RADIO TELEMETERING THEODOLITE AND USE OF ITS DATA

PURPOSE: The purpose of this tech memo is to show how the Radio Telemetering Theodolite (RTT) basically works, and what data is used from the recording for glide slope structure analysis.

NARRATIVE: The flight inspection of a glide slope facility is accomplished to verify the radiated signal meets the specified tolerances in the United States Standard Flight Inspection Manual, AFM 55-8. Various checks of the signal are made. Ultimately, however, the primary feature which determines the adequacy of the radiated signal is the condition, or structure, of the on-path signal. A smooth structure may allow instrument approaches to be made closer to the runway, either by autopilot or manually. A rough structure, however, may restrict a facility to manual approaches only, or to a certain altitude or distance past which the signal is unreliable.

The best way to examine glide path structure is through the use of an RTT. The basic purpose of an RTT is to set up another "glide path," at a frequency of 329.0 MHz (a special frequency allocated specifically for flight inspections). This glide path, however, is "perfect." The eyepiece of the RTT is set at the expected glide angle of the facility being inspected. The RTT itself is normally positioned so the eyepiece angle is aligned with the glide path origin, which is considered to be the base of the antenna tower. The RTT's 90 Hz and 150 Hz signals are adjusted so they are balanced symmetrically around the eyepiece angle. The width of the RTT "glide path" is also adjusted to the expected width of the facility being inspected.

When the aircraft flies the real glide path, the RTT operator tracks the aircraft movement with the RTT eyepiece. The RTT sends the aircraft a signal to show where the aircraft should be if it were flying a perfect glide path. A differential receiver in the aircraft compares the RTT signal with the signal of the real glide path. The algebraic difference between the two shows the deviation of the actual glide path from the "perfect" glide path produced by the RTT. The major advantage of using the RTT is the aircraft does not always have to be exactly on-path. When the aircraft deviates from on-path, the RTT tells the aircraft differential receiver the aircraft is deviating, effectively cancelling the aircraft movement in the differential trace.

As an analogy, think of the RTT signal as a "string" positioned at the glide angle as depicted in Figure 1. As the aircraft slides down the string, it records the difference between the "string" and the actual glide path. The "string" (the centerline of the differential trace) provides the reference from which we can analyze the structure of the actual glide path.

The flight inspection of glide slope facilities includes measurement of structure in Zones 1, 2, and 3, as shown in Figure 2. In Zone 1, the aircraft's distance from the site makes it difficult to accurately track the aircraft with the RTT eyepiece. The differential trace in Zone 1 usually has little or no structure indications which can be representative of the true glide path. Use of Zone 3 is undesirable because the information there is subject to tracking errors by the RTT operator from too much aircraft movement. The data collected in Zone 2 is used for most glide slope analysis because it is far enough out to minimize tracking errors but close enough in to depict any

ATTACHMENT 1

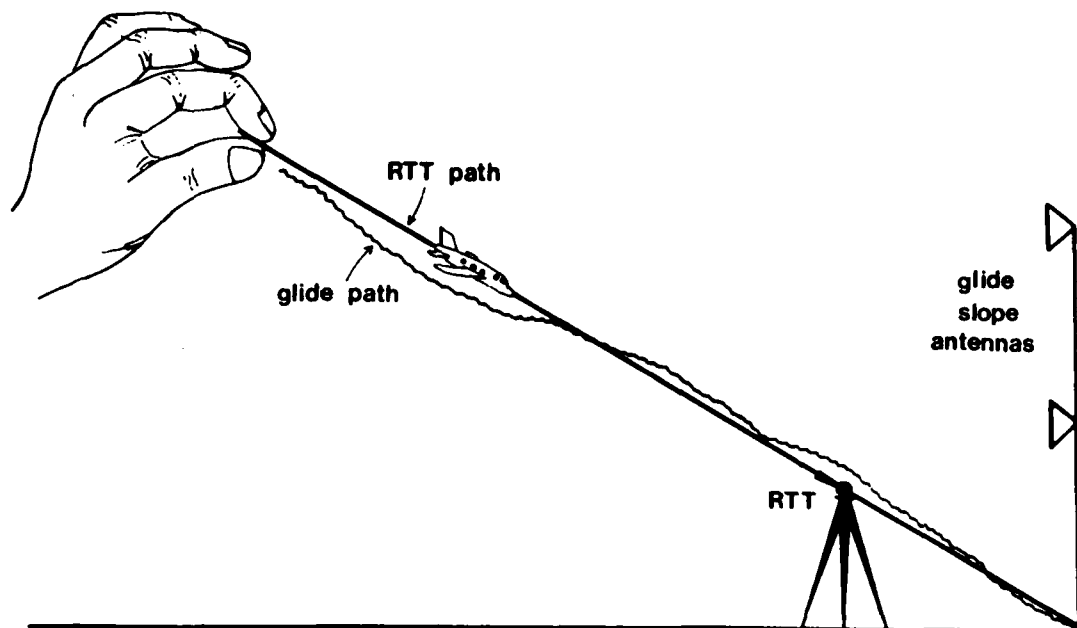


Figure 1
RTT Analogy

glide path anomalies. Zone 2 is also the critical sector of the aircraft descent, where transition from instrument to visual approach is usually accomplished or missed approach procedures are implemented.

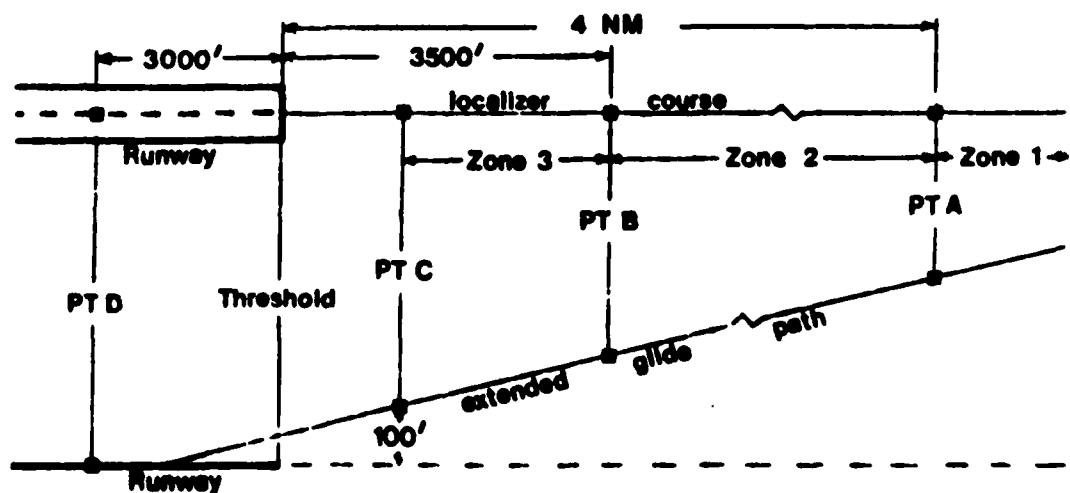


Figure 2
ILS Reference Points and Zones

ATTACHMENT 1

Use of an RTT for glide slope structure runs provides a constant stream of recorded information from which we can sample data. A sample aircraft structure recording is shown in Figure 3. The structure data shown by the differential trace is sampled at regular intervals in Zone 2. If distance marks are available on the recording, they can be converted to nautical miles from the glide slope facility. If distance marks are unavailable, the timing lines can be used with the aircraft speed to find distances. Procedures for establishing distance scales on glide slope structure recordings are presented in TM(N)-20. Where the differential trace is sampled, the difference between the recording centerline (eyepiece angle) and the trace is measured to determine the structure of the facility.

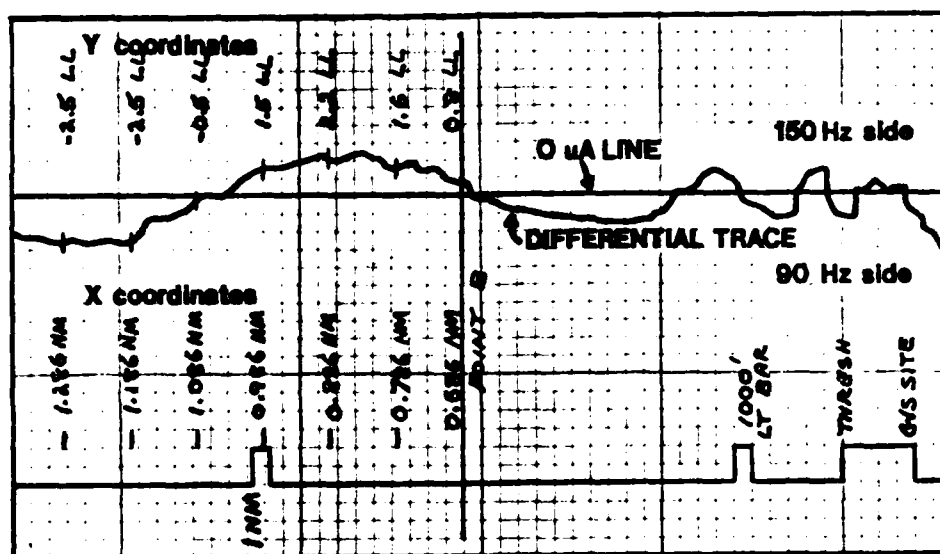


Figure 3
Sample Aircraft Structure Recording

Submitted By: 1866 FCS/TE, 1Lt Leister
30 May 1981

TECH MEMO

TITLE: DETERMINING TCH USING THE HEIGHTS OF POINTS A AND B

PURPOSE: The purpose of this tech memo is to demonstrate how to arrive at a value for TCH using the heights of a model or actual glide path data at Points A and B.

NARRATIVE: TCH is defined in AFM 55-8 as the straight line extension of the glide path projected above the runway threshold. If we establish the straight line portion of the glide path, either for actual data or through the use of a model, then simple trigonometric relationships can be used to find a value for TCH. Two convenient points to use in establishing the straight line glide path are Points A and B. These points and the other ILS reference points and zones are shown in Figure 1.

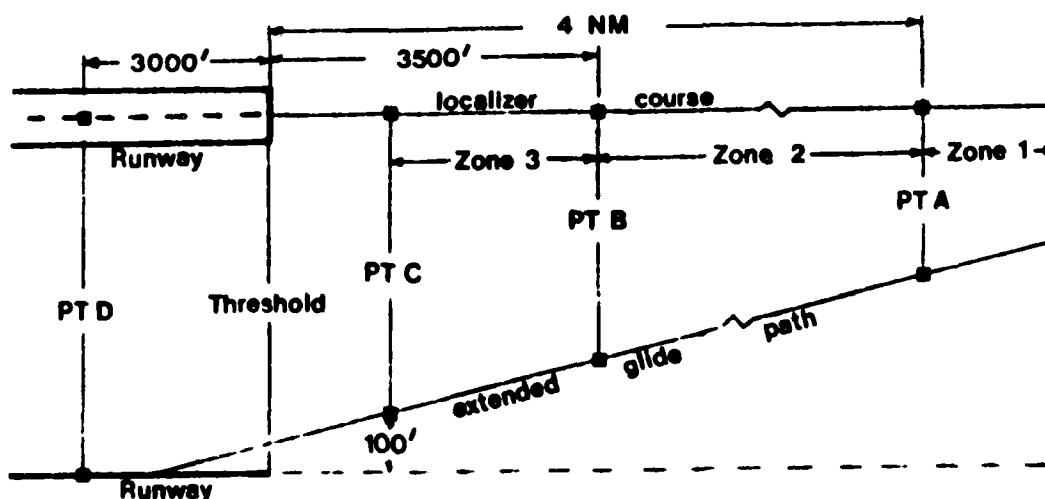


Figure 1
ILS Reference Points and Zones

There is little disagreement that Point A is located in the linear portion of the glide path. Point B, however, is located in the area where the glide path is beginning to flare. How much error in the height of Point B is produced by glide path flare? This can be demonstrated by calculating the height at Point B, first using the distance from the point on the runway centerline abeam the glide slope site, and then the diagonal distance from the glide slope site, which takes into account the offset distance of the glide slope facility from the runway centerline. For a 3.0° glide angle, an offset distance of 500 feet, and a distance to threshold of 1200 feet, the error in the height of Point B caused by glide path flare is about 1.4 feet, or less than 1%. Therefore, we can assume the height of Point B is in the linear portion of the glide path and can be used to calculate a value for TCH.

ATTACHMENT 2

The heights at Points A and B are found in two ways. The first and simplest method is through the use of the GSSTAT Program, which automatically calculates the heights of various glide path models at Points A and B. The second method is to use the structure recording, determine the location of Points A and B on the recording, and measure the light line values of the differential trace (See TM(N)-20 for this procedure). However, the RTT must be verified to be optimally placed before structure recording data can be used. The heights at Points A and B (or any point along the glide path) can be found by the following equation:

$$H_i = D_i \tan (\theta + (LL_i)(W/40))$$

Where D_i = Horizontal distance of the point from the glide slope in feet.

θ = Center eyepiece angle of the RTT in degrees.

LL_i = Light line value of the differential trace at the point being evaluated.

W = Path width set into the RTT in degrees.

The heights of Points A and B in the GSSTAT Program are also computed in this manner. Remember, these heights are referenced from the elevation of the antenna tower base because the RTT eyepiece is backsighted to this point.

Once we have the heights at Points A and B, we can use the diagram in Figure 2 and some simple trigonometric relationships to derive an equation for calculating TCH.

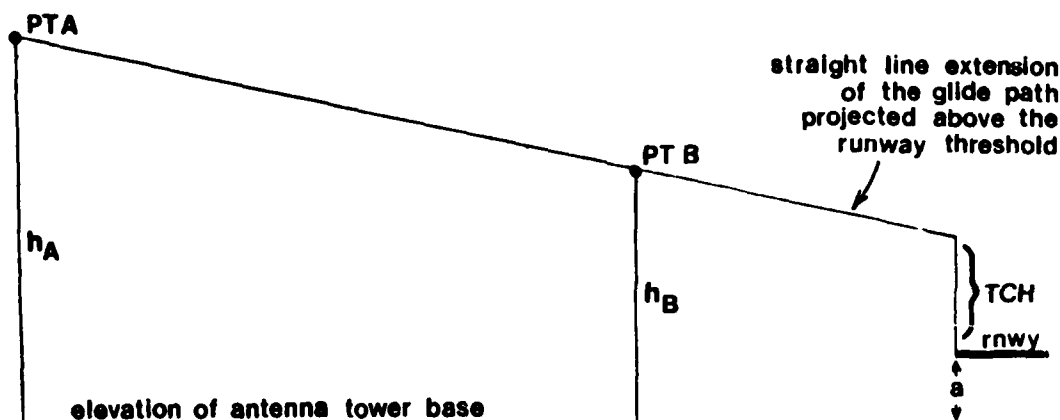


Figure 2
Determination of TCH with Heights of Points A and B

The equation for finding TCH from the heights of Points A and B is derived below:

$$\frac{h_A - (TCH + a)}{24304} = \frac{h_B - (TCH + a)}{3500}$$

ATTACHMENT 2

$$3500h_A - 3500(TCH + a) = 24304h_B - 24304(TCH + a)$$

$$20804(TCH + a) = 24304h_B - 3500h_A$$

$$TCH = \frac{24304h_B - 3500h_A}{20804} - a$$

Where h_A = Height at Point A in feet
 h_B = Height at Point B in feet
 a = Threshold elevation - antenna pad elevation in feet

Because the heights are referenced from the elevation of the antenna tower base, the elevation difference between the glide slope site and the threshold must be accounted for. (Hence, the constant "a" in the above equation).

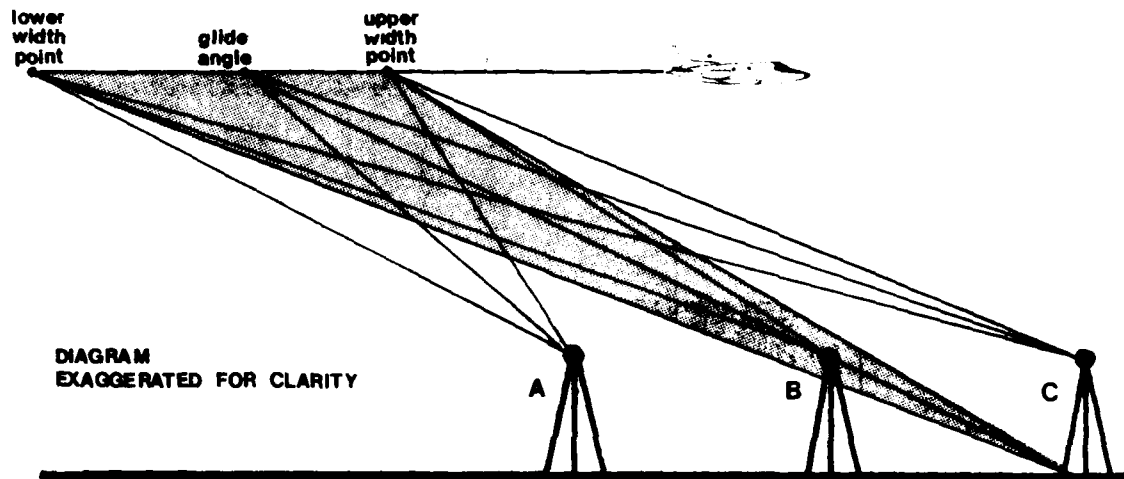
Submitted by: 1866 FCS/TE, Lt Leister
15 May 1980

ATTACHMENT 3

TITLE

EFFECT OF THEODOLITE PLACEMENT ON WIDTH AND ANGLE RUNS

The placement of the theodolite has a slight effect on the data collected during a width and angle run. For example, assume the aircraft makes a level run at 1000 feet AGL. With a constant radiation pattern, the width and angle points will always be in the same place, as shown in the diagram below. Now let's choose three theodolite locations A, B, and C. A is positioned 100 feet in front of the extended glide path, B is positioned on the extended glide path, and C is positioned 100 feet behind the extended glide path. The theodolites are 5.24 feet high. Using geometry, we can calculate the effects of the different view-points (theodolite locations) on the angles of the width and angle points. Assume the glide angle is 3.00° . The results are shown in the table below.



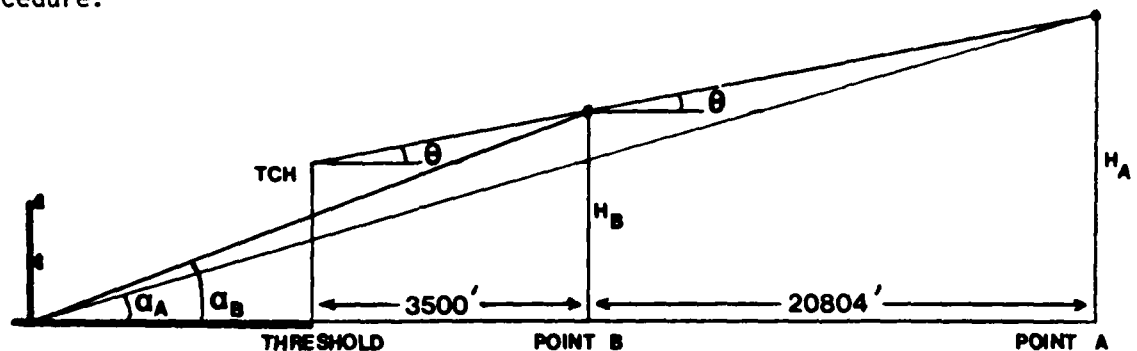
	ACTUAL GLIDE PATH	VIEWS FROM LOCATION A	VIEWS FROM LOCATION B	VIEWS FROM LOCATION C
LOWER WIDTH POINT	2.650°	2.661°	2.649°	2.637°
UPPER WIDTH POINT	3.350°	3.373°	3.353°	3.333°
GLIDE PATH ANGLE	3.000°	3.017°	3.001°	2.985°
PATH WIDTH	0.700°	0.712°	0.704°	0.696°
SYMMETRY	50%/50%	50%/50%	50%/50%	50%/50%

The results indicate that a theodolite position in front of (or below) the extended glide path will have a tendency to increase the angle and width. Conversely, a theodolite position behind (or above) the extended glide path will have a tendency to decrease the angle and width. The symmetry remains unaffected by the theodolite position. Terrain effects can also play a role in affecting the observed angle and width. The magnitude of these changes, however, even with the amount of theodolite misplacement shown here, is hardly measurable on the flight inspection recordings and not reportable on flight inspection reports.

TITLE:

FLIGHT RECORDING ANALYSIS WITH LINEAR REGRESSION

Linear regression on glide slope structure recordings can be accomplished with most any combination of coordinate units. X coordinates can be in feet, nautical miles, or in seconds. Y coordinates can be in uA, feet, light-lines, or degrees. The most common and easiest to use is seconds and light-lines because these are readily available on the recording. When seconds are used, the starting point is not critical as long as the linear regression is drawn based on the same starting point. For uniformity, Point B can be used as the starting point. Then the seconds can be incremented toward Point A. With equal units the glide angle is readily found as the arctangent of the slope of the linear regression. With unequal units, however, the glide angle cannot be determined from the linear regression. This problem can be overcome using the following diagram and procedure.



1. Determine the value of the linear regression in light lines at Point A and Point B. Convert these light line values to degrees (α_A and α_B , respectively).
2. The height of the glide path at Points A and B can be calculated from the equation below.

$$H = D \tan \alpha$$

where H = height of glide path at each point
 D = distance from the glide slope site to each point
 α = degree value of the linear regression at each point

3. The glide angle for the facility is found from the following equation.

$$\theta = \arctan \left(\frac{H_A - H_B}{20804} \right)$$

The distance from the glide slope can be used because we originally set the RTT to backsight the antenna base at minus the commissioned or desired glide angle. We can therefore treat our viewpoint of the linear regression as the antenna base without incurring appreciable error. The antenna base location is easily found in the facility data sheets. If we convert H_A and H_B using step (2), and in terms of the facility offset distance (d_{off}) and distance to threshold (d_o), we get the following equation for the glide angle.

$$\theta = \tan^{-1} \left\{ \frac{\sqrt{d_{off}^2 + [d_o + 24304]^2} \tan \alpha_A - \sqrt{d_{off}^2 + [d_o + 3500]^2} \tan \alpha_B}{20804} \right\}$$

ATTACHMENT 5

TITLE: RTT POSITIONING ANALYSIS SUMMARY																																	
LOCATION Wright-Patterson AFB	DATE July 1978																																
<p>Diagram of RTT placement on runway 05 Diagram is not drawn to scale.</p>																																	
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 25%;"></th> <th style="width: 25%;">POSITION 1</th> <th style="width: 25%;">POSITION 2</th> <th style="width: 25%;">POSITION 3</th> <th style="width: 25%;">POSITION 4</th> </tr> </thead> <tbody> <tr> <td>AVERAGE ANGLE</td> <td>3.06°</td> <td>3.07°</td> <td>3.02°</td> <td>3.06°</td> </tr> <tr> <td>STRUCTURE ZONE 1</td> <td>8uA/5.8NM</td> <td>7uA/4.9NM</td> <td>9uA/5.3NM</td> <td>8uA/5.9NM</td> </tr> <tr> <td>STRUCTURE ZONE 2</td> <td>19uA/2.1NM</td> <td>15uA/2.1NM</td> <td>15uA/2.5NM</td> <td>17uA/2.9NM</td> </tr> <tr> <td>STRUCTURE ZONE 3</td> <td>23uA/0.6NM</td> <td>15uA/0.9NM</td> <td>12uA/0.8NM</td> <td>12uA/0.8NM</td> </tr> <tr> <td>TRUE GLIDE ANGLE</td> <td>3.04°</td> <td>3.05°</td> <td>3.02°</td> <td>3.03°</td> </tr> </tbody> </table> <table border="1" style="width: 60%; margin: auto; border-collapse: collapse;"> <tr> <td style="text-align: center; padding: 5px;"> AVERAGE OF AVERAGE ANGLES: 3.05° STANDARD DEVIATION: 0.022 </td> </tr> <tr> <td style="text-align: center; padding: 5px;"> AVERAGE OF TRUE GLIDE ANGLES: 3.04° STANDARD DEVIATION: 0.019 </td> </tr> </table>			POSITION 1	POSITION 2	POSITION 3	POSITION 4	AVERAGE ANGLE	3.06°	3.07°	3.02°	3.06°	STRUCTURE ZONE 1	8uA/5.8NM	7uA/4.9NM	9uA/5.3NM	8uA/5.9NM	STRUCTURE ZONE 2	19uA/2.1NM	15uA/2.1NM	15uA/2.5NM	17uA/2.9NM	STRUCTURE ZONE 3	23uA/0.6NM	15uA/0.9NM	12uA/0.8NM	12uA/0.8NM	TRUE GLIDE ANGLE	3.04°	3.05°	3.02°	3.03°	AVERAGE OF AVERAGE ANGLES: 3.05° STANDARD DEVIATION: 0.022	AVERAGE OF TRUE GLIDE ANGLES: 3.04° STANDARD DEVIATION: 0.019
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REMARKS																																	

ATTACHMENT 5

TITLE: RTT POSITIONING ANALYSIS SUMMARY	
LOCATION Wright-Patterson AFB	DATE April 1979

Diagram of RTT placement on runway 05
Diagram is not drawn to scale.

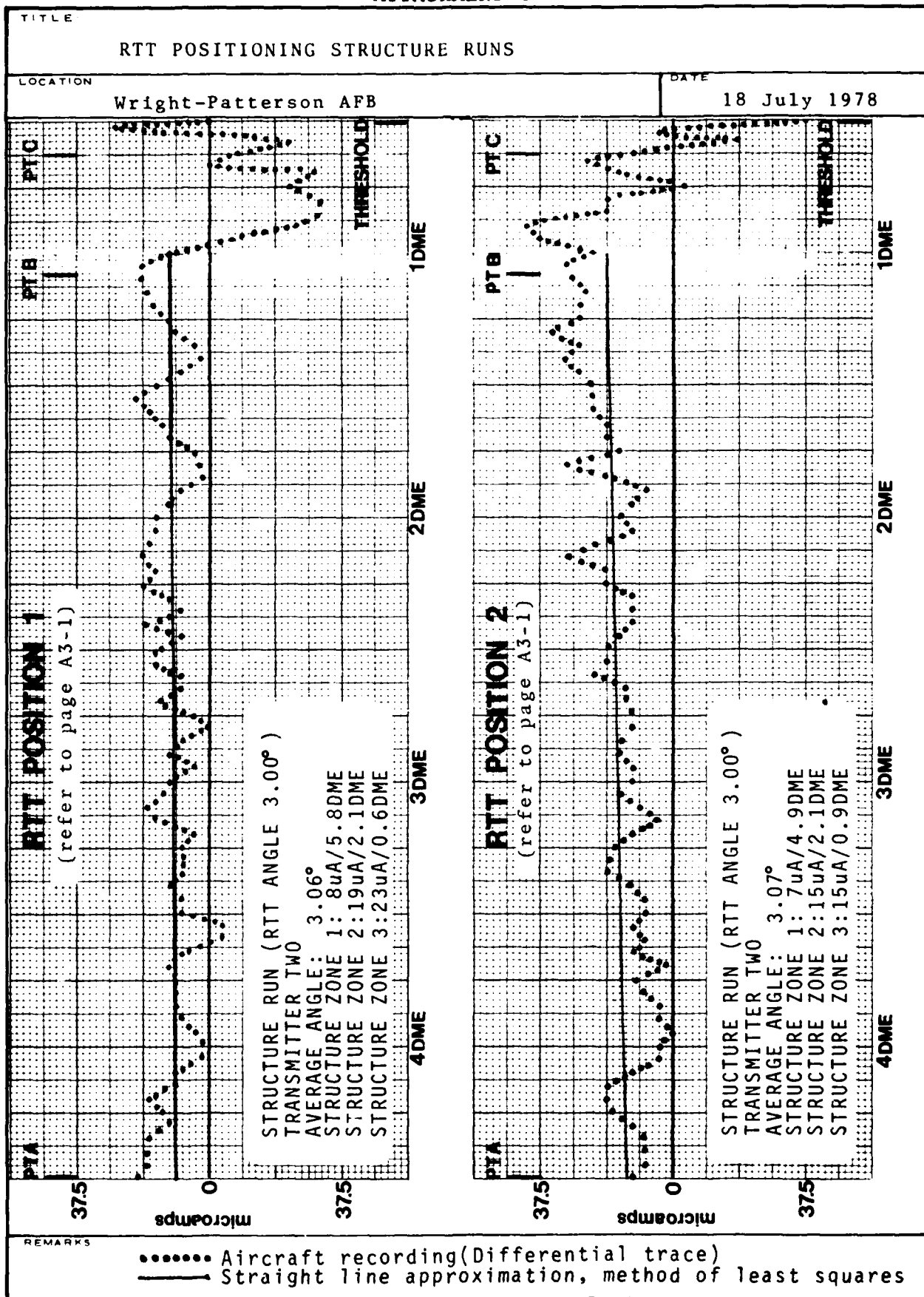
	THEO PAD	POSITION 1	POSITION 2	POSITION 3	POSITION 4
AVERAGE ANGLE	3.04°	3.09°	3.08°	3.05°	3.07°
STRUCTURE ZONE 1	4uA/7.0NM	3uA/5.1NM	4uA/5.0NM	1uA/4.1NM	8uA/4.1NM
STRUCTURE ZONE 2	11uA/4.1NM	19uA/0.7NM	11uA/2.6NM	12uA/1.8NM	18uA/0.6NM
STRUCTURE ZONE 3	12uA/0.3NM	10uA/0.2NM	10uA/0.3NM	9uA/0.3NM	19uA/0.3NM
TRUE GLIDE ANGLE	3.07°	3.09°	3.09°	3.10°	3.11°

AVERAGE OF AVERAGE ANGLES: 3.07°
STANDARD DEVIATION: 0.021

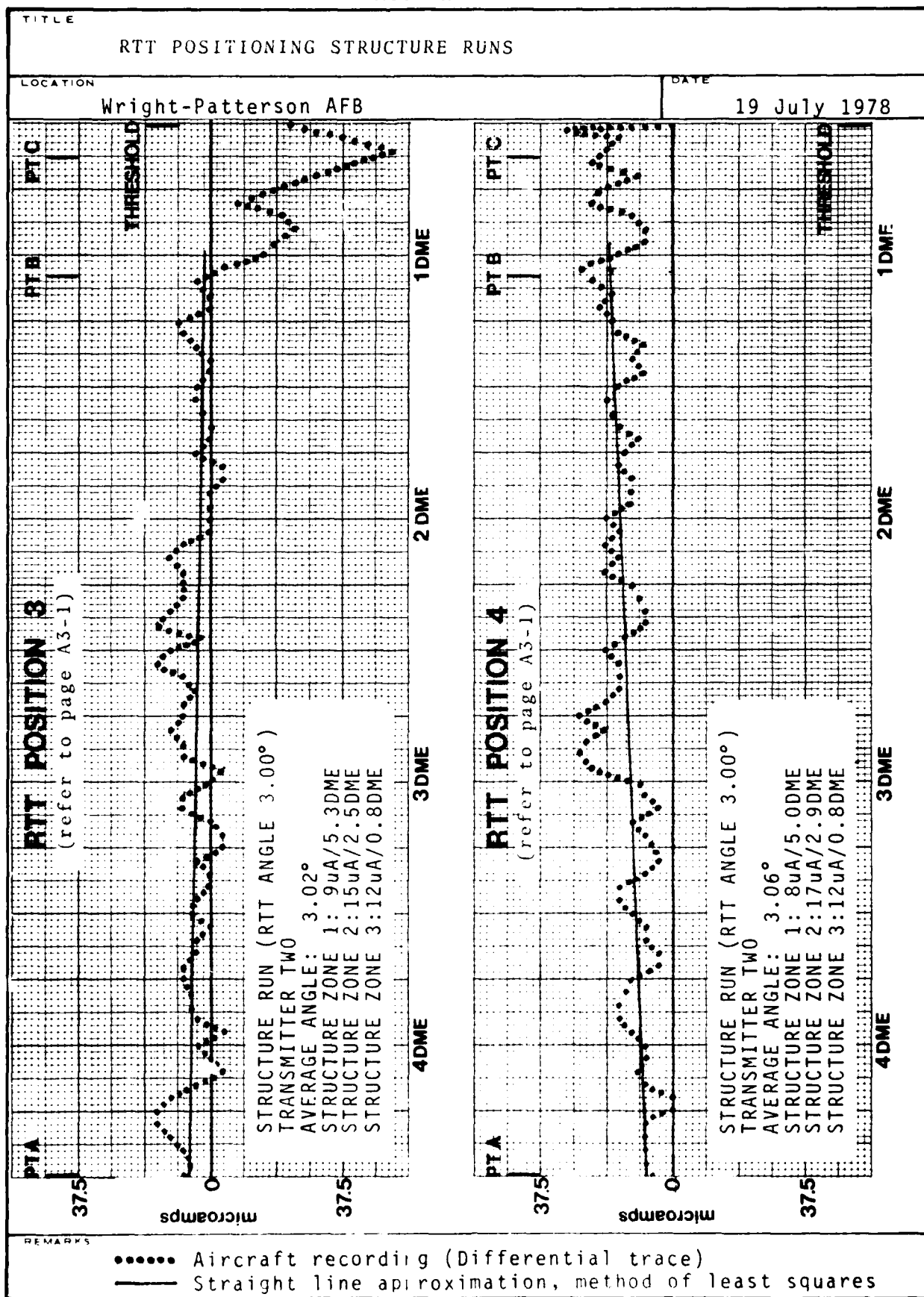
AVERAGE OF TRUE GLIDE ANGLES: 3.09°
STANDARD DEVIATION: 0.015

The true glide angle values are more closely grouped than those for the average angle, based on the standard deviations. The values for the true glide angle are a better indication of the actual glide angle.

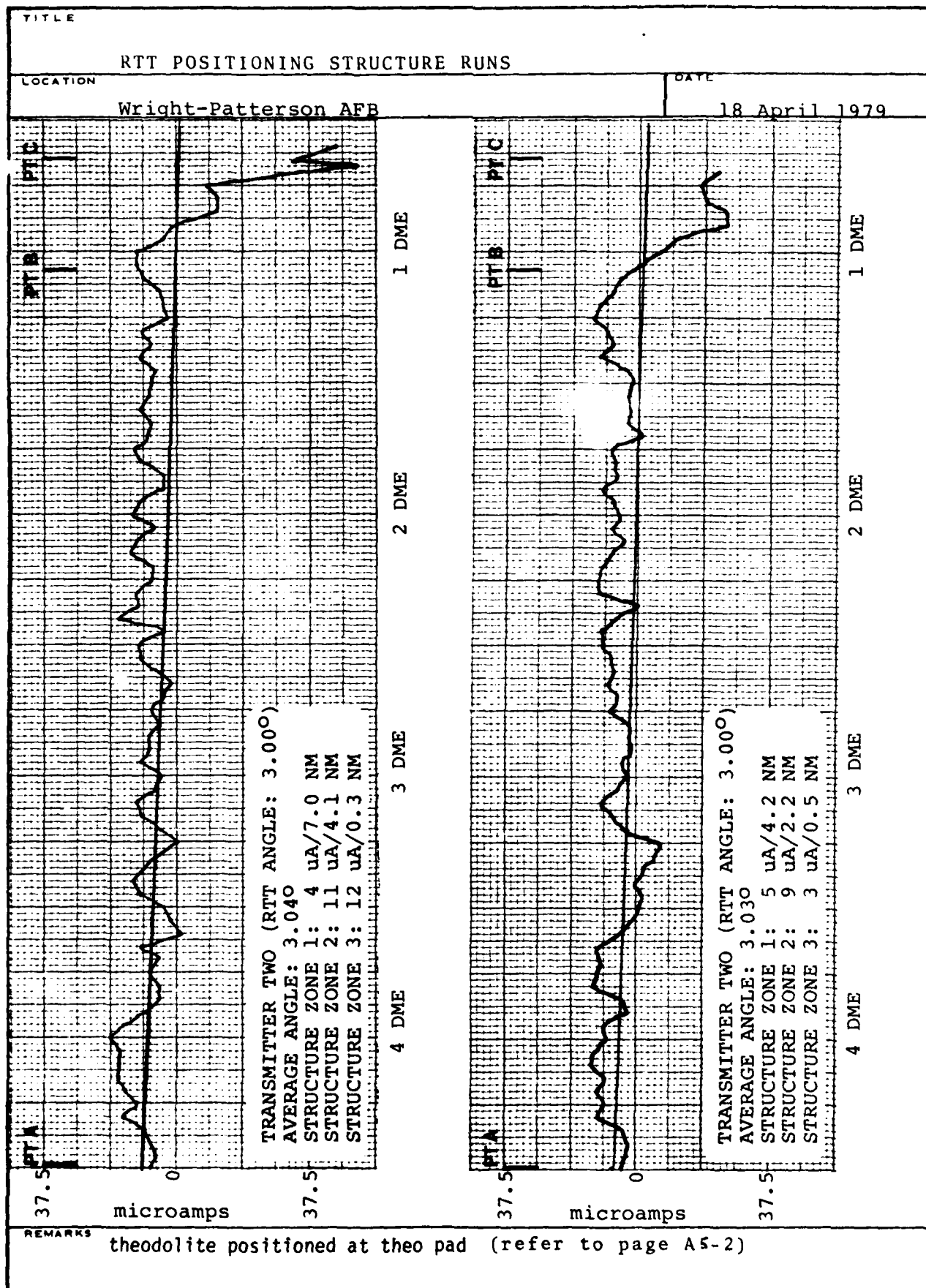
ATTACHMENT 6



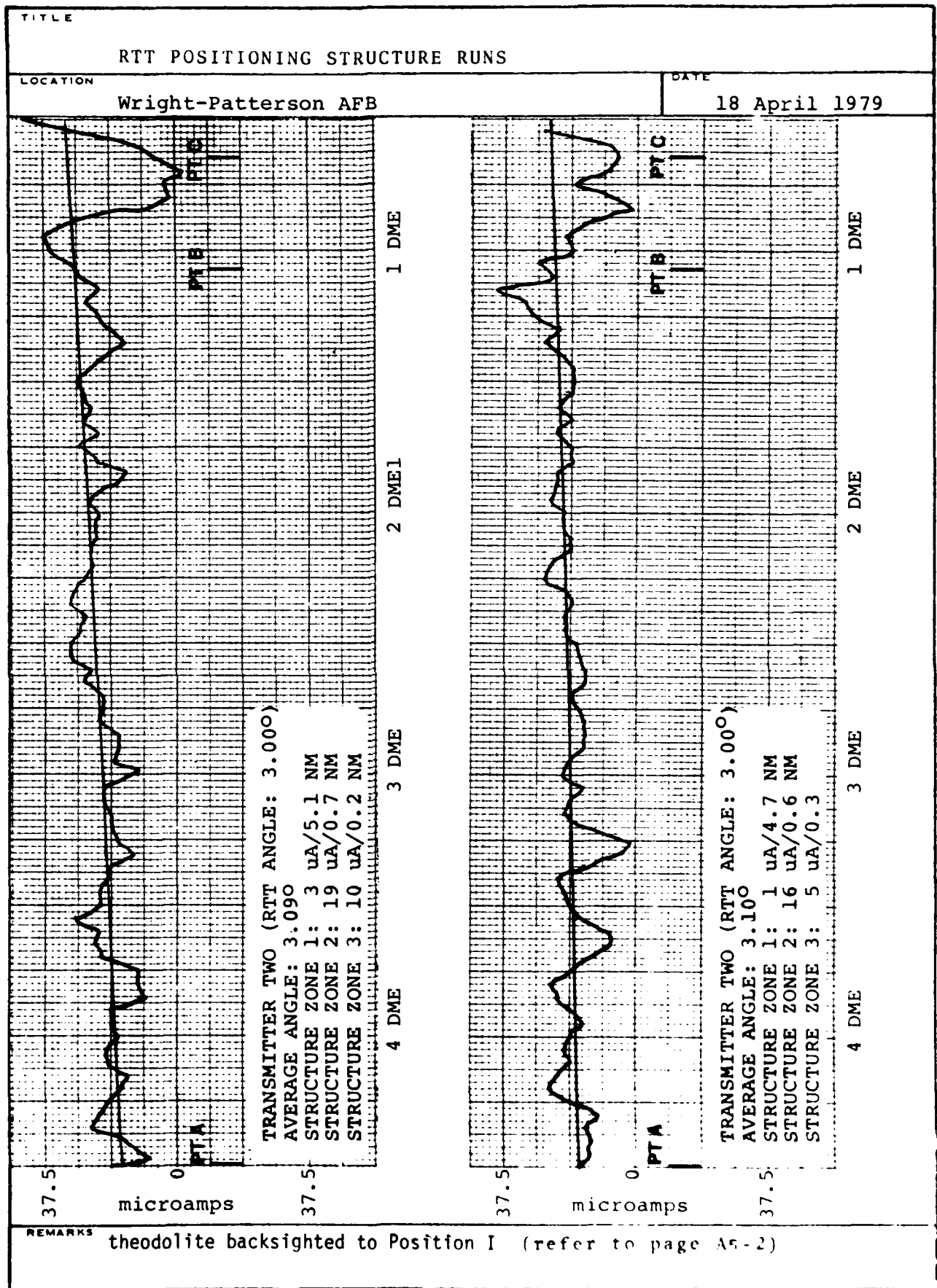
ATTACHMENT 6



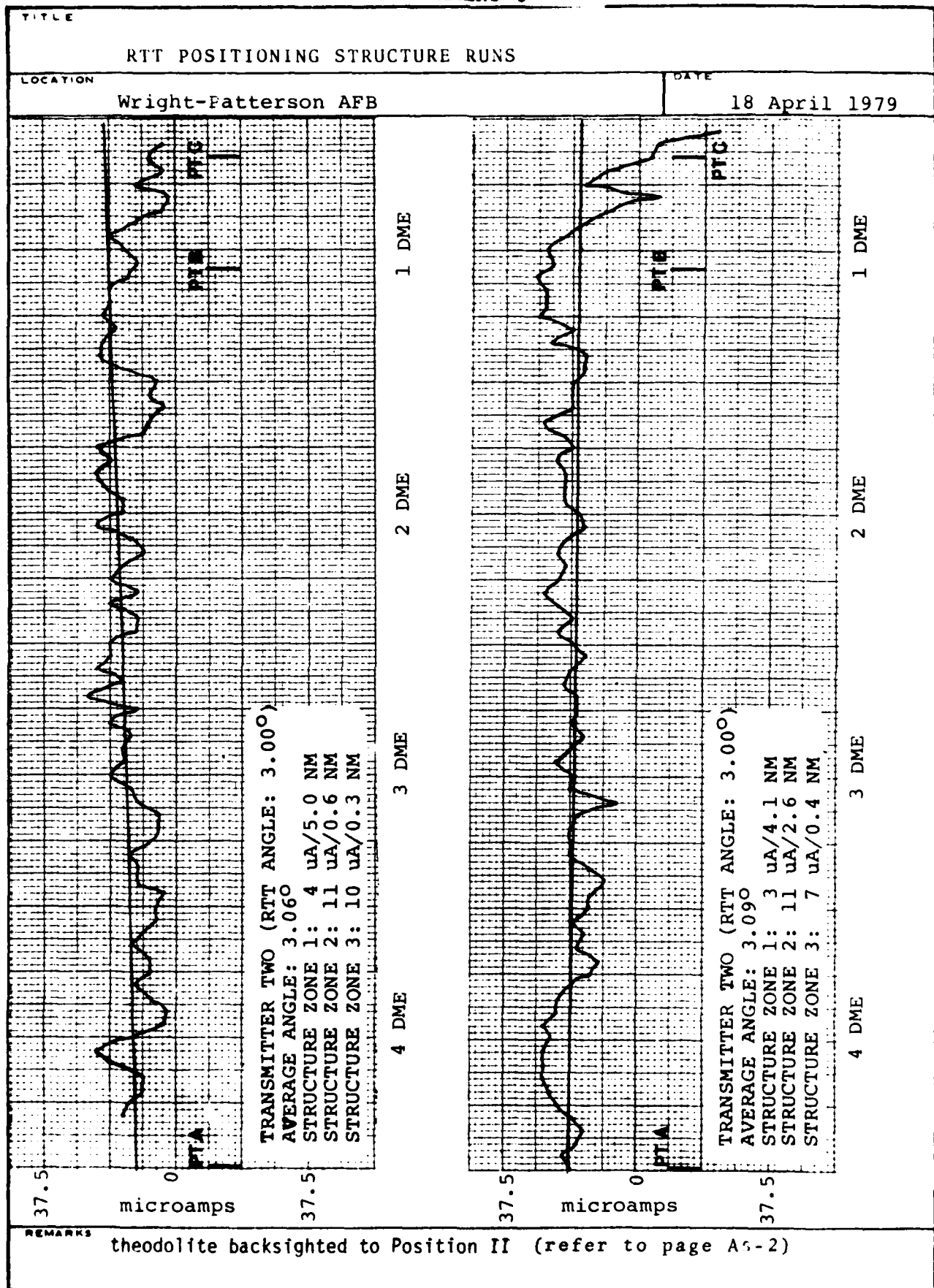
ATTACHMENT 6



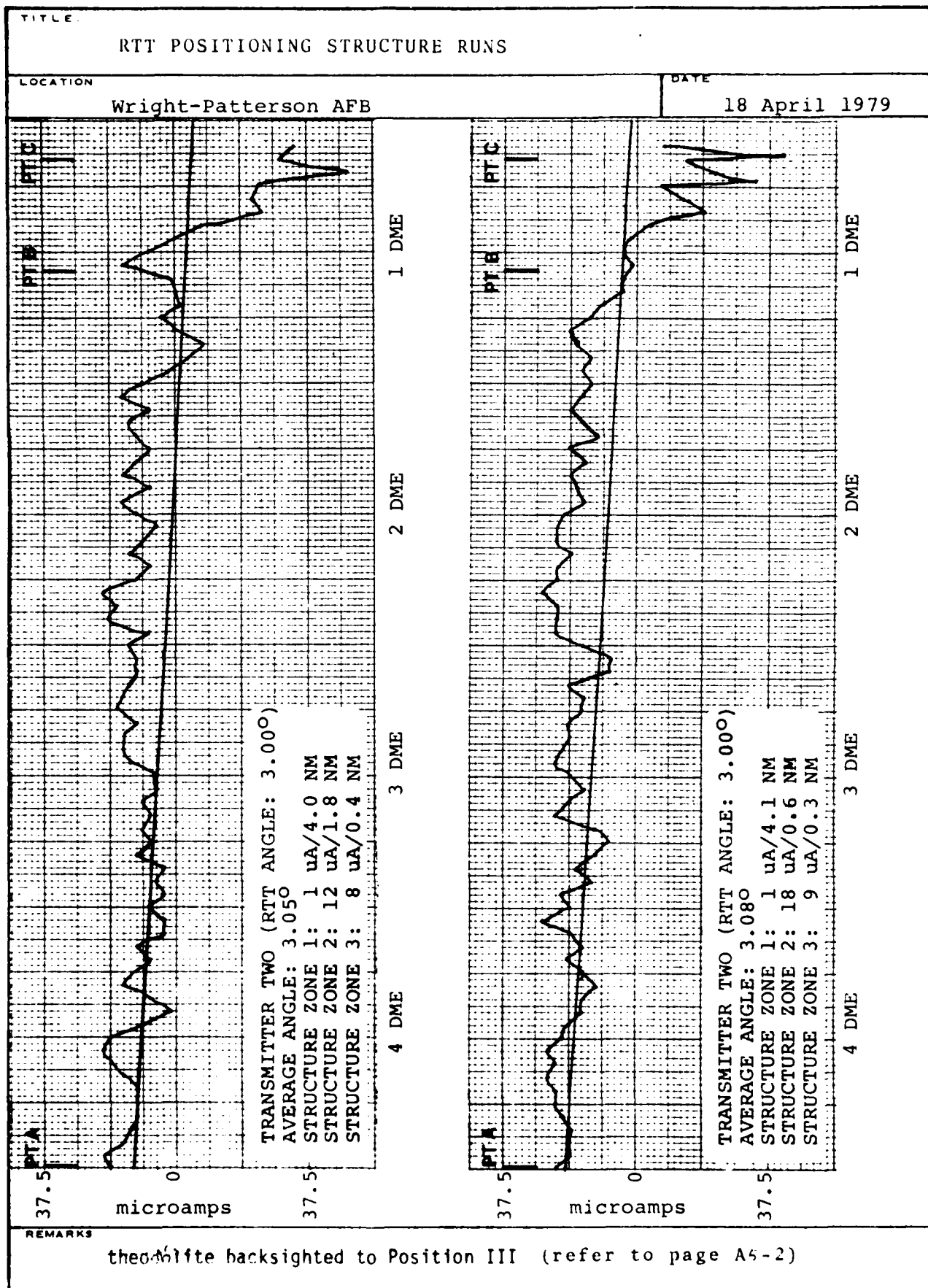
ATTACHMENT 6



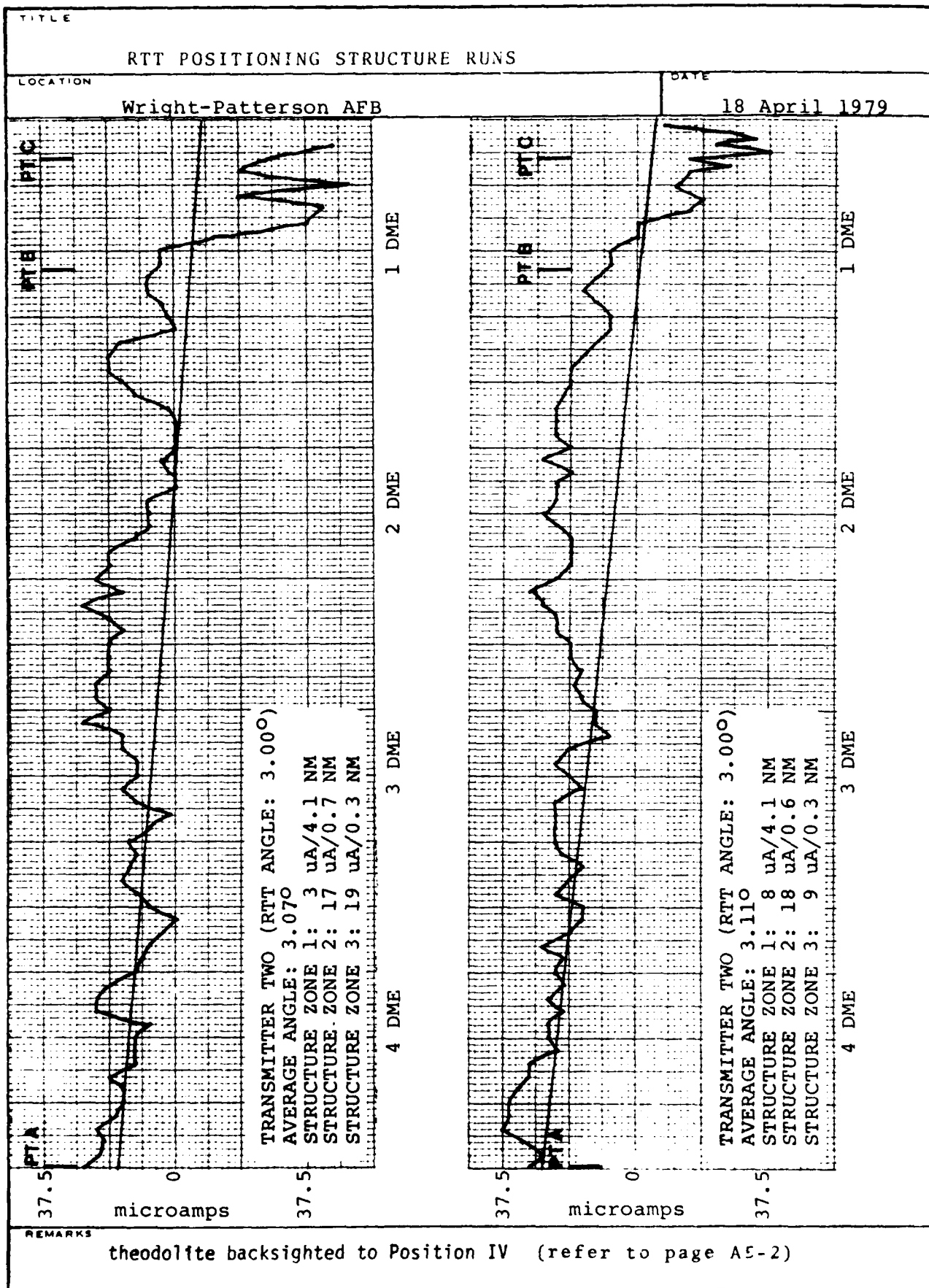
ATTACHMENT 6



ATTACHMENT 6



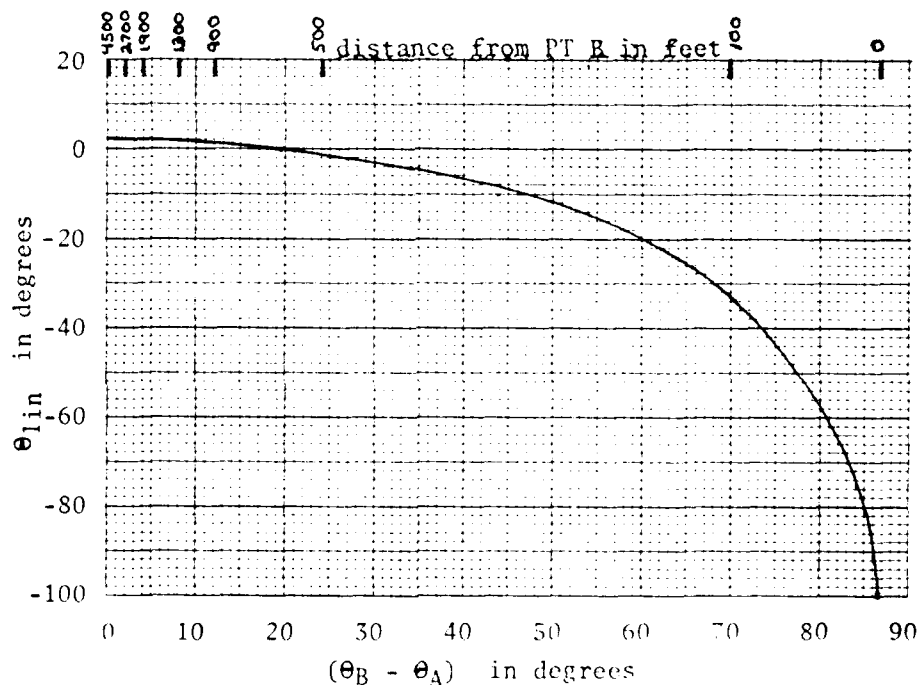
ATTACHMENT 6



ATTACHMENT 7

THE EFFECT OF VIEWPOINT ON LINEAR REGRESSION ANGLE CALCULATIONS

The graph below illustrates the effect of viewpoint proximity to the linear regression as used in this procedure. The linear regression is considered to be a straight line between Points A and B at an angle of 3.00° from the horizontal. The projection of the linear regression intersects the reference plane at a point 1000 feet from the runway threshold (the "origin"), or 4500 feet from Point B. As we move the viewpoint along the runway centerline to Point B, we examine the viewing angles to Points A and B, as well as the value for the linear regression angle produced by the procedure. The linear regression angle (θ_{lin}) is plotted against the difference between the viewing angles ($\theta_B - \theta_A$). The distance from Point B is marked along the top of the graph.



The graph shows the procedure becomes increasingly inaccurate as the viewpoint becomes closer to Point B. When the viewpoint is directly under Point B ($\theta_B = 90^\circ$), the linear regression angle goes to negative infinity. However, when the viewpoint is in the vicinity of the apparent origin, the linear regression angle remains very near its actual value of 3.00° . The distance scale becomes extremely compressed at this point as well, which indicates that as long as the initial viewpoint is in the vicinity of the apparent origin, the procedure will evaluate the correct linear regression angle and therefore be valid.

ATTACHMENT 8

TITLE

HP-25 PROGRAM FOR LINEAR REGRESSION

This program is based on the Hewlett-Packard HP-25 program for linear regression. It has been slightly modified to compute the average light line value as well as the regression constants a_1 and a_0 , based on the following equation.

$$Y = a_1(X) + a_0$$

Y is the value in light lines of the recording data point, and X is the distance from the glide slope. The distance can be in any units, as long as the linear regression is drawn on the flight recording in the same units. For use on the flight recordings, data points should be taken at least every two seconds, and if time permits, every second.

Below is the key sequence for the program itself. The next page provides instructions for using the program. It is assumed the user is familiar with the operation of the HP-25 programmable calculator.

DISPLAY LINE	CODE	KEY ENTRY	COMMENTS	DISPLAY LINE	CODE	KEY ENTRY	COMMENTS
00			Steps 1 thru 7 for summation	25	32	CHS	Halt to display A_0 Halt to display A_1 Display r^2 Coefficient of determination Display average $Y's$
01	31	\uparrow		26	24 04	RCL 4	
02	15 02	$g X^2$		27	51	+	
03	23 51 02	STO+2		28	24 03	RCL 3	
04	22	$R\downarrow$		29	71	\div	
05	21	$X \leftrightarrow Y$		30	23 00	STO 0	
06	25	$\Sigma +$		31	74	R/S	
07	13 00	GTO 00		32	24 01	RCL 1	
08	24 05	RCL 5		33	74	R/S	
09	24 07	RCL 7		34	21	$X \leftrightarrow Y$	
10	24 04	RCL 4		35	22	$R\downarrow$	
11	61	X		36	61	X	
12	24 03	RCL 3		37	24 02	RCL 2	
13	71	\div		38	24 04	RCL 4	
14	41	-		39	15 02	$g X^2$	
15	24 06	RCL 6		40	24 03	RCL 3	
16	24 07	RCL 7		41	71	\div	
17	15 02	$g X^2$		42	41	-	
18	24 03	RCL 3		43	71	\div	
19	71	\div		44	74	R/S	
20	41	-		45	24 04	RCL 4	
21	71	\div		46	24 03	RCL 3	
22	23 01	STO 1		47	71	\div	
23	24 07	RCL 7		48	13 00	GTO 00	
24	61	X					

MEMORY REGISTERS

$R_0 = a_0$ $R_4 = \Sigma Y$
 $R_1 = a_1$ $R_5 = \Sigma XY$
 $R_2 = \Sigma Y^2$ $R_6 = \Sigma X^2$
 $R_3 = n$ $R_7 = \Sigma X$

REMARKS: The value on line 14 is also needed near the end of the program to find the coefficient of determination. Since all registers are in use, the only place to store this value is in the stack. Because of its presence, do not disturb the stack.

TITLE

HP-25 PROGRAM FOR LINEAR REGRESSION

The following is a set of instructions and keystrokes to use with the program on the preceding page. Once the program is entered and initialized, the user inputs the paired values of data (X_i, Y_i), $i = 1, \dots, n$. When all the data points have been entered, the regression constants a_1 and a_0 may be calculated.

A third value, the coefficient of determination (r^2) is also found. The value of r^2 will lie between 0 and 1, and will indicate how closely the equation fits the data; the closer r^2 is to 1, the better the fit. When the equation is solved with coordinates such as light lines and nautical miles, r^2 will not be close to 1 because the units disagree. If the time is taken to convert the coordinates to the same units, such as feet, then r^2 will be greatly improved. This is not necessary, however, since the linear regression is the best fit equation no matter what r^2 is.

STEP	INSTRUCTIONS	INPUT	KEYS				OUTPUT
1	Key in the program		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2	Initialize program		f	Rec	f	PRG	
3	Perform for $i=1, \dots, n$	X_i	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
		Y_i	R/S	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	i
4	Compute regression constants		GTO	00	R/S	<input type="checkbox"/>	a_0
			R/S	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	a_1
5	Compute coefficient of determination		R/S	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	r^2
6	Compute average of Y's		R/S	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	$\frac{\sum Y}{n}$
7	To find Y, input X	X	RCL	1	X	RCL	
			0	+	<input type="checkbox"/>	<input type="checkbox"/>	Y
8	Perform step 7 as needed		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
9	For new case, go to 2.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

If X coordinates are taken every second, Step 3 can be simplified somewhat. Choose the first data point and call $X = 0$. Punch the ENTER \uparrow key. Enter the Y value and punch R/S. The display will show 1. Now punch ENTER \uparrow key again. Enter next Y value and punch R/S. Now the display shows 2. Continue this process for all the data points. This allows the program to use the data point number to increment the X coordinate. The data points can be entered much quicker and time is saved in computing the X coordinates.

<h1>PROGRAM RECORD</h1>		CALCULATOR TYPE TI-59 with PC 100A/C		PAGE 1 OF 1	
		PROGRAMMER 1Lt M. K. McCullough		DATE June 1961	
PROGRAM TITLE TI-59 Program for Optimum RTT Placement					
PARTITIONING (OP 17) 4 7 9 5 9		CARD NUMBER(S) 1 / MASTER Library Module			
PROGRAM DESCRIPTION					
<p>The Optimum RTT Position program provides the team chief/ engineer with a rapid method for the evaluation of the placement location of the radio telemetry theodolite (RTT). From information off of the flight recording of an RTT run, the engineer can assess the trend of the crosspointer trace and determine statistically whether the RTT is in front of, behind, or on the correct position to properly track the flight inspection aircraft.</p>					
USER INSTRUCTIONS					
STEP	PROCEDURE	ENTER	PRESS		DISPLAY
1	Initialize the program after reading card.	CLR or Ø	2nd	E'	0
2	Enter the G/S to threshold distance dØ.	distance ft	2nd	A'	dØ
3	Enter the G/S offset distance doff.	distance ft	2nd	B'	dB
4	Enter the RTT eyepiece angle. Øeye.	angle deg	2nd	C'	Øeye
5	Enter the terrain slope S.	slope deg	2nd	D'	S
6	Enter the number of seconds to Point A	time sec	C		Pt A
7	Enter the number of seconds to Point B	time sec	D		Pt B
8	Enter 999 for auto X or first X-value.	999 or val	A		Ø or value
9	Enter Y (light line) value.	value	B		summation indx
10	Repeat 8 & 9 or 9 depending on mode (automatic X-value or manual X-value entry). Repeat until all data points are entered into the calculator.				
11	Calculate ØA, ØB, Ølin, avg ang, Dtheo and RTT move. If the linear regression is desired to be printed enter one, else Ø	1 or Ø	E		RTT move ft
12	Reinitialize the program for another analysis		2nd	E'	
USER DEFINED KEYS		DATA REGISTERS (INV ON)		LABELS (OP 06)	
A X-value input	1 ⁰ Pt A in sec	2 ⁰ Theta A (ØA)			
B Y-value input	1 ¹ Pt B in sec	2 ¹ Theta B (ØB)			
C Seconds to Pt A	1 ² dØ in feet	2 ² Theta lin (Ølin)			
D Seconds to Pt B	1 ³ doff in feet	2 ³ Avg angle			
E Execute	1 ⁴ dB in feet	2 ⁴ Dtheo			
A dØ input	1 ⁵ Ø eye	2 ⁵ RTT move			
B doff input	1 ⁶ terrain slope	2 ⁶ temp storage			
C Øeye input	1 ⁷ X manual buffer	7			
D Slope input	1 ⁸ x auto indx buffer	Ø ⁸ 11 to deg factor			
E Initialization	1 ⁹ Y input buffer	Ø ⁹ temp buffer			
FLAGS					
0	1	2	3	4	5
6	7	8	9		
Auto X	LinRegPrt				

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
000	76	LBL	Y-value input	055	67	EQ	Check for 999 input to flag Auto X	110	42	STD	
001	12	B		056	88	DMS		111	09	09	
002	42	STD		057	04	4		112	01	1	
003	19	19		058	04	4		113	06	6	
004	87	IFF	check for auto X	059	71	SBR		114	00	0	
005	01	01		060	99	PRT		115	01	1	
006	23	LNK		061	91	R/S		116	71	SBR	
007	43	RCL		062	76	LBL		117	99	PRT	
008	17	17		063	88	DMS		118	91	R/S	
009	32	X:T		064	86	STF	Set flag for Auto X	119	76	LBL	
010	61	STD		065	01	01		120	17	B'	deff input
011	60	DEG		066	43	RCL		121	42	STD	
012	76	LBL	-----	067	11	11		122	13	13	
013	23	LNK		068	75	-		123	42	STD	
014	02	2	Auto X-in index sec	069	02	2		124	09	09	
015	44	SUM		070	95	=		125	01	1	
016	18	18		071	42	STD		126	06	6	
017	43	RCL		072	18	18		127	03	3	
018	18	18		073	25	CLR		128	02	2	
019	42	STD		074	91	R/S		129	02	2	
020	09	09		075	76	LBL		130	01	1	
021	32	X:T		076	99	PRT	Printer output subroutine	131	02	2	
022	04	4		077	69	OP		132	01	1	
023	04	4		078	04	04		133	71	SBR	
024	71	SBR	Print 'X'	079	43	RCL		134	99	PRT	
025	99	PRT	-----	080	09	09		135	33	X ²	
026	76	LBL		081	69	OP		136	85	+	
027	60	DEG		082	06	06		137	53	(
028	43	RCL		083	92	RTN		138	43	RCL	
029	19	19		084	76	LBL	initialization sequence	139	12	12	
030	42	STD		085	10	E'		140	85	+	
031	09	09		086	36	PGM		141	03	3	
032	04	4		087	01	01		142	05	5	
033	05	5		088	71	SBR		143	00	0	
034	71	SBR	Print 'Y'	089	25	CLR		144	00	0	
035	99	PRT		090	93	.	light line to degree multiplctn factor	145	54)	
036	78	Σ+	Sum to lin reg array	091	00	0		146	33	X ²	
037	43	RCL		092	01	1		147	95	=	
038	03	03		093	07	7		148	34	FX	
039	91	R/S		094	05	5		149	42	STD	
040	76	LBL		095	42	STD		150	14	14	
041	11	A	X- value input	096	08	08		151	42	STD	
042	42	STD		097	22	INV		152	09	09	
043	17	17		098	86	STF		153	01	1	
044	42	STD		099	01	01		154	06	6	
045	09	09		100	22	INV		155	01	1	
046	87	IFF	error trap for auto X	101	86	STF		156	04	4	
047	01	01		102	02	02		157	71	SBR	
048	12	B		103	98	ADV		158	99	PRT	
049	09	9		104	25	CLR		159	91	R/S	
050	09	9		105	91	R/S		MERGED CODES			
051	09	9		106	76	LBL		62	PPG	IND	
052	32	X:T		107	16	A'	dø input	72	STD	IND	
053	43	RCL		108	42	STD		83	GRN	END	
054	09	09		109	12	12		63	TRF	IND	
								73	RCL	IND	
								84	BY	PPG	
								64	TRF	IND	
								74	SUM	IND	
								92	INV	SBR	
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LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS				
160	76	LBL	eye input	215	03	3	Execute Calculations	270	42	STD	Calc 01lin				
161	18	C'		216	03	3		271	21	21					
162	42	STD		217	03	3		272	42	STD					
163	15	15		218	07	7		273	09	09					
164	42	STD		219	00	0		274	03	3					
165	09	09		220	00	0		275	07	7					
166	03	3		221	01	1		276	02	2					
167	07	7		222	04	4		277	03	3					
168	02	2		223	71	SBR		278	01	1					
169	03	3		224	99	PRT		279	04	4					
170	05	5		225	98	ADV		280	71	SBR					
171	04	4		226	91	R/S		281	99	PRT					
172	71	SBR	227	76	LBL	282	66	PAU							
173	99	PRT	228	15	E	283	43	RCL							
174	91	R/S	229	32	X/T	284	14	14							
175	76	LBL	230	01	1	285	65	*							
176	19	D'	231	67	EQ	286	43	RCL							
177	42	STD	232	70	RAD	287	21	21							
178	16	16	233	43	RCL	288	30	TAN							
179	42	STD	234	10	10	289	95	=							
180	09	09	235	69	DP	290	94	+/-							
181	03	3	236	14	14	291	42	STD							
182	06	6	237	65	*	292	09	09							
183	02	2	238	43	RCL	293	43	RCL							
184	07	7	239	08	08	294	12	12							
185	03	3	240	95	=	295	85	+							
186	03	3	241	85	+	296	02	2							
187	71	SBR	242	43	RCL	297	04	4							
188	99	PRT	243	15	15	298	03	3							
189	98	ADV	244	95	=	299	00	0							
190	91	R/S	245	42	STD	300	04	4							
191	76	LBL	246	20	20	301	95	=							
192	13	C	247	42	STD	302	33	X ²							
193	42	STD	248	09	09	303	85	+							
194	10	10	249	03	3	304	43	RCL							
195	42	STD	250	07	7	305	13	13							
196	09	09	251	02	2	306	33	X ²							
197	03	3	252	03	3	307	95	=							
198	03	3	253	01	1	308	34	FX							
199	03	3	254	03	3	309	65	*							
200	07	7	255	71	SBR	310	43	RCL							
201	00	0	256	99	PRT	311	20	20							
202	00	0	257	66	PAU	312	30	TAN							
203	01	1	258	43	RCL	313	95	=							
204	03	3	259	11	11	314	85	+							
205	71	SBR	260	69	DP	315	43	RCL							
206	99	PRT	261	14	14	316	09	09							
207	98	ADV	262	65	*	317	95	=							
208	91	R/S	263	43	RCL	318	55	+							
209	76	LBL	264	08	08	319	02	2							
210	14	D	265	95	=	MERGED CODES									
211	42	STD	266	85	+	62	for	ind	72	sto	ind	83	ifo	ind	
212	11	11	267	43	RCL	63	for	ind	73	rcl	ind	84	for	ind	
213	42	STD	268	15	15	64	for	ind	74	sum	ind	92	inv	SBR	
214	09	09	269	95	=	PAGE 3 OF 4									

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LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
320	00	0		375	94	+/-		430	99	PRT	
321	08	8		376	85	+		431	98	ADV	
322	00	0		377	01	1		432	98	ADV	
323	04	4		378	95	=		433	87	IFF	
324	95	=		379	65	x		434	02	02	Test for
325	22	INV		380	43	RCL		435	28	LOG	lin reg prt
326	30	TAN		381	14	14		436	91	R/S	
327	95	=		382	95	=		437	76	LBL	
328	42	STD		383	42	STD		438	70	RAD	Set flag
329	22	22		384	24	24		439	86	STF	for lin reg
330	42	STD		385	42	STD		440	02	02	print out
331	09	09		386	09	09		441	25	CLR	
332	03	3		387	01	1		442	98	ADV	
333	07	7		388	06	6		443	15	E	
334	02	2		389	03	3		444	76	LBL	
335	07	7		390	07	7		445	28	LOG	linear
336	02	2		391	02	2		446	43	RCL	regression
337	04	4		392	03	3		447	11	11	print out
338	03	3		393	03	3		448	42	STD	subroutine
339	01	1		394	02	2		449	26	26	
340	71	SBR		395	71	SBR		450	76	LBL	
341	99	PRT		396	99	PRT		451	37	P/R	
342	66	PAU		397	66	PAU		452	43	RCL	
343	79	x	Average	398	43	RCL	RTT move	453	26	26	
344	65	x	Angle Calc	399	22	22	calculation	454	42	STD	
345	43	RCL		400	38	SIN		455	09	09	
346	08	08		401	55	÷		456	04	4	
347	85	+		402	53	(		457	04	4	
348	43	RCL		403	53	(		458	71	SBR	
349	15	15		404	43	RCL		459	99	PRT	
350	95	=		405	22	22		460	69	OP	
351	42	STD		406	75	-		461	14	14	
352	23	23		407	43	RCL		462	42	STD	
353	42	STD		408	16	16		463	09	09	
354	09	09		409	54	)		464	04	4	
355	06	6		410	38	SIN		465	05	5	
356	07	7		411	54	)		466	71	SBR	
357	01	1		412	95	=		467	99	PRT	
358	03	3		413	65	x		468	02	2	
359	03	3		414	43	RCL		469	44	SUM	
360	01	1		415	24	24		470	26	26	
361	02	2		416	95	=		471	43	RCL	
362	02	2		417	42	STD		472	10	10	
363	71	SBR		418	25	25		473	32	X!T	
364	99	PRT		419	42	STD		474	43	RCL	
365	66	PAU		420	09	09		475	26	26	
366	98	ADV		421	03	3		476	77	GE	
367	43	RCL	Dtheo calc	422	00	0		477	10	E'	
368	21	21		423	03	3		478	61	GTO	
369	30	TAN		424	02	2		479	37	P/R	
370	55	÷		425	04	4		MERGED CODES			
371	43	RCL		426	02	2		62	INT	INT	
372	22	22		427	01	1		72	STO	STO	
373	30	TAN		428	07	7		83	GTO	GTO	
374	95	=		429	71	SBR		63	INT	INT	
								73	RCL	RCL	
								64	INT	INT	
								74	SUM	SUM	
								84	INT	INT	
								92	INV	SBR	
								PAGE 4 OF 4			

ATTACHMENT 9

TI-59 Program for Optimum RTT Placement

INTRODUCTION

This guide contains the information necessary to run the program for the Leister Method of RTT Placement written for the TI-59 calculator. The program can be run on the calculator alone or on the calculator/printer combination. The program is enhanced for use with the PC-100/A or C printers.

DESCRIPTION

The RTT Method program provides the Team Chief/Engineer with a rapid method for evaluating the placement location for the radio telemetry theodolite (RTT). From information off of the flight recording of an RTT run, the engineer can assess the trend of the crosspointer trace and determine statistically whether the RTT is in front of, behind, or on the correct position to properly track the flight inspection aircraft. Data needed to input into the program include:

1. The distance in feet the glide slope antenna is from the servicing runway's threshold -- this is symbolized as D0
2. The distance in feet the glideslope antenna is from the servicing runway's centerline -- Doff
3. The general terrain slope in degrees from in front of the glide slope antenna to 200 feet out -- S
4. The RTT eyepiece angle in degrees -- θ_{eye}
5. The time in seconds it took the aircraft to fly from Point A to the glide slope antenna -- for θ_A calculation.
6. The time in seconds it took the aircraft to fly from Point B to the glide slope antenna -- for θ_B calculation.
7. The light line value of the crosspointer at some time increment -- y
8. Finally, the time in seconds from the glide slope antenna each light line value was taken off of the flight recording -- x.

The program uses linear regression to find the trend of the light line values (y) over time (x) in between Point A and Point B -- the straight-line portion of the glide path. The origin of the linear regression line is extrapolated to the runway centerline abeam the glide slope antenna base. The program then computes the trend line angle (θ_{lin}) from the data parameters in 1, 2, 6, and 7 above.

USER INSTRUCTIONS

After both sides of the TI-59 magnetic storage program card are read into the calculator, the program must be initialized. Simply press the E' key (2nd E key). The program

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is now initialized.

Next, the user needs to enter the parameters described in 1 through 6 above. DO is entered through A', Doff is entered through B', -Oeye is entered through C', S is entered through D', the number of seconds from the glide slope antenna to Point A is entered through C, (the glide slope antenna is the time origin; the time count starts at zero there and increases to Point A. Thus, x can be thought of as time to go until the aircraft reaches the point abeam the glide slope antenna), and finally, the time in seconds to Point B is entered through D. If the printer is being used, each of these values entered are printed out and identified for verification.

The user is now ready to input the linear regression data points. The flight inspection recording is held so that the light line values are entered as positive if the trace is on the 150-Hz side of the zero crosspointer line and negative if the trace is on the 90-Hz side of the zero crosspointer line. This usually means that the glide slope antenna mark on the recording will be at the user's right and the Point A mark will be at the user's left. The program can be operated in two different modes. One mode is for the program to automatically provide the time increment (x) for the linear regression. This default time increment is two seconds. The user simply inputs the flight inspection recording light line value (y) at this default value from Point B to Point A.

The second mode the program can be run in is for the user to provide the values of the time (x) when the light line value (y) is measured. This allows the user the freedom to utilize this program when an RTT run is not possible, but barrel runs are. Since the theodolite operator's on call marks are generally not constant over time, the user can input the y-value and x-value of the on call marks and construct the linear regression from these.

Therefore, if the user desires the program to default the x-values, simply enter the number 999 through the A key. This causes the program to be flagged for automatic x-value entry. Thereafter, only the y-values have to be entered in the program through the B key. There is an error trap in case mistake is made and the A key is accidentally hit when entering a y-value. The y-value will be entered as if the B key was pressed.

If the user wishes to enter both of the data values then the x-value is entered through the A key followed by the y-value through the B key.

This key sequence is continued in either case until all of the data points are entered. The display of the calculator will show a counter increment of how many data points have been entered into the program. If the printer is being used, the values are printed out and are identified as x-values or y-values. If a mistake is made in data point entry, it can be

ATTACHMENT 9

removed by using the trend data point removal instructions in the TI-59 handbook or the little booklet provided with the solid-state library module.

Once the linear regression data is entered, the formula computations can begin. The program will compute θA , θB , θ_{lin} , the average angle, D_{theo} , and X -- the final resultant move for the theodolite. The program again has two modes at this point.

If the user is using the printer and wants the values of the linear regression to be printed out; press the 1 key and then the E key. If it is not desired to have this extra information, then press the 0 key or the CLR key and then the E key.

Finally, the moment of triumph! The calculated theodolite move is displayed and also printed if you are using the printer. Remember, if the value is positive then move the theodolite forward toward the threshold. If it is negative, then move it back. If the distance to move the theodolite is computed to be less than 15 feet, the move should be considered to be insignificant.

If the user wishes to keep the facility data, simply save it onto another magnetic card by writing side 4 on the card. The information in the memories is listed below:

Register Location	Register Contents
00 thru 07	used as linear regression array
08	light-line to degrees factor
09	temporary storage buffer
10	time to Point A in seconds
11	time to Point B in seconds
12	d0 in feet
13	doff in feet
14	dB in feet
15	θ_{eye} in degrees
16	terrain slope in degrees
17	x-value manual input buffer
18	x-value automatic index buffer
19	y-value input buffer
20	θA resultant storage
21	θB resultant storage
22	θ_{lin} resultant storage
23	average angle resultant storage
24	D_{theo} resultant storage
25	Theodolite move storage

To compute another RTI run, simply re-initialize the program and re-enter the facility data and the new recording data in the mode desired.

ATTACHMENT 10

LIST

```

10 DIM D1(100); DIM D2(100)
20 REM START THE GRAPHICS FOR OPTIMUM RTT POSITION.
30 HOME : GR
40 COLOR= 6: PLOT 3,10: PLOT 15,15: PLOT 26,15: PLOT 19,10
50 COLOR= 13: PLOT 13,30: PLOT 3,35: PLOT 26,35: PLOT 35,24
60 COLOR= 12: PLOT 12,20: PLOT 12,22: PLOT 25,25: PLOT 17,20
70 COLOR= 6: PLOT 8,15: PLOT 21,15: PLOT 30,10: PLOT 27,10
80 COLOR= 13: PLOT 11,30: PLOT 14,30: PLOT 22,30: PLOT 18,35
90 COLOR= 6: PLOT 6,15: PLOT 11,11: PLOT 36,10: PLOT 27,10
100 COLOR= 12: PLOT 15,25: PLOT 19,23: PLOT 27,20: PLOT 23,20
110 COLOR= 13: PLOT 6,31: PLOT 28,30: PLOT 28,35: PLOT 36,20
120 COLOR= 6: PLOT 32,10: PLOT 34,14: PLOT 30,15: PLOT 15,10
130 COLOR= 13: PLOT 16,35: PLOT 36,35: PLOT 26,30: PLOT 13,35
140 COLOR= 12: PLOT 12,25: PLOT 19,25: PLOT 21,20: PLOT 25,22
150 COLOR= 6: PLOT 27,15: PLOT 25,10: PLOT 19,15: PLOT 6,12
160 COLOR= 13: PLOT 3,30: PLOT 22,35: PLOT 33,33: PLOT 8,31
170 COLOR= 12: PLOT 12,25: PLOT 14,23: PLOT 19,24: PLOT 26,20
180 COLOR= 6: PLOT 3,15: PLOT 10,13: PLOT 22,12: PLOT 25,14
190 COLOR= 13: PLOT 10,35: PLOT 11,32: PLOT 16,30: PLOT 24,31
200 COLOR= 6: PLOT 8,10: PLOT 13,10: PLOT 23,15: PLOT 33,12
210 COLOR= 13: PLOT 33,35: PLOT 26,34: PLOT 31,32: PLOT 24,20
220 COLOR= 6: PLOT 15,14: PLOT 24,13: PLOT 30,10: PLOT 32,15
230 COLOR= 13: PLOT 3,33: PLOT 18,31: PLOT 36,32: PLOT 31,35
240 COLOR= 6: PLOT 3,12: PLOT 21,10: PLOT 27,13: PLOT 36,12
250 COLOR= 12: PLOT 15,21: PLOT 13,23: PLOT 19,21: PLOT 15,24
260 COLOR= 6: PLOT 4,10: PLOT 19,12: PLOT 33,13: PLOT 25,11
270 COLOR= 13: PLOT 16,30: PLOT 34,32: PLOT 29,30: PLOT 5,33
280 COLOR= 6: PLOT 17,10: PLOT 11,12: PLOT 23,14: PLOT 30,11
290 COLOR= 13: PLOT 11,35: PLOT 13,35: PLOT 20,30: PLOT 28,32
300 COLOR= 6: PLOT 15,11: PLOT 21,13: PLOT 32,11: PLOT 34,15
310 COLOR= 13: PLOT 35,33: PLOT 22,31: PLOT 8,33: PLOT 15,30
320 COLOR= 6: PLOT 8,13: PLOT 27,11: PLOT 32,13: PLOT 19,13
330 COLOR= 12: PLOT 25,21: PLOT 16,20: PLOT 15,22: PLOT 25,24
340 COLOR= 13: PLOT 9,30: PLOT 14,33: PLOT 26,35: PLOT 36,34
350 COLOR= 6: PLOT 6,10: PLOT 10,10: PLOT 30,13: PLOT 21,12
360 COLOR= 13: PLOT 5,30: PLOT 18,35: PLOT 31,30: PLOT 22,34
370 COLOR= 6: PLOT 3,14: PLOT 24,12: PLOT 29,15: PLOT 35,13
380 COLOR= 13: PLOT 33,30: PLOT 23,30: PLOT 13,31: PLOT 6,32
390 COLOR= 12: PLOT 12,23: PLOT 19,20: PLOT 25,20: PLOT 14,20
400 COLOR= 6: PLOT 6,14: PLOT 25,13: PLOT 36,11: PLOT 8,12
410 COLOR= 13: PLOT 3,31: PLOT 11,33: PLOT 29,33: PLOT 33,31
420 COLOR= 6: PLOT 15,12: PLOT 35,12: PLOT 16,10: PLOT 5,15
430 COLOR= 13: PLOT 30,35: PLOT 26,31: PLOT 18,30: PLOT 10,30
440 COLOR= 6: PLOT 3,11: PLOT 22,13: PLOT 36,14: PLOT 27,14
450 COLOR= 13: PLOT 9,35: PLOT 14,35: PLOT 31,31: PLOT 36,33
460 COLOR= 6: PLOT 6,11: PLOT 25,15: PLOT 30,14: PLOT 9,13
470 COLOR= 13: PLOT 11,31: PLOT 16,34: PLOT 31,34: PLOT 33,34
480 COLOR= 12: PLOT 12,24: PLOT 20,20: PLOT 25,23: PLOT 13,20
490 COLOR= 13: PLOT 29,35: PLOT 4,33: PLOT 22,32: PLOT 8,30
500 COLOR= 6: PLOT 19,14: PLOT 32,12: PLOT 6,13: PLOT 9,10
510 COLOR= 13: PLOT 3,32: PLOT 15,33: PLOT 28,34: PLOT 18,34
520 COLOR= 6: PLOT 4,15: PLOT 36,13: PLOT 21,11: PLOT 30,12
530 COLOR= 13: PLOT 8,34: PLOT 30,30: PLOT 13,32: PLOT 36,31
540 COLOR= 6: PLOT 8,14: PLOT 29,15: PLOT 19,11: PLOT 15,13

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ATTACHMENT 10

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100 PLOT 17,12: PLOT 17,12: PLOT 15,15: PLOT 28,31: PLOT 11,34
110 PLOT 12,11: COLOR= 6: PLOT 21,14: PLOT 5,10: PLOT 27,12
120 PLOT 3,34: PLOT 22,13: PLOT 31,33: PLOT 18,32
130 PLOT 24,14: COLOR= 8: PLOT 7,13: PLOT 14,10: PLOT 25,11
140 PLOT 8,32: PLOT 21,30: PLOT 10,20: COLOR= 12: PLOT 19,22
150 PLOT 9, 6: PLOT 8,11: PLOT 20,14: COLOR= 13: PLOT 4,30: PLOT 26,32
160 PLOT 3,25
170 HOME: HOME: PRINT "BY HARVEY LEISTER": PRINT ""
180 ATAB 5: PRINT "PRESS ANY KEY TO BEGIN.": CALL - 756: D% = "": TEXT: HOME
190 PRINT "THIS PROGRAM PROVIDES A METHOD TO DETER-
200 PRINT "MINALLY POSITION AN RTT FOR VIEWING THE
210 PRINT "STRUCTURE ON A GLIDE SLOPE FACILITY."
220 PRINT "THIS IS DONE USING AN INITIAL POSITION"
230 PRINT "USUALLY THE RTT BACKSITED TO THE GLIDE"
240 PRINT "SLOPE ANTENNA BASE), AND RECORDING A"
250 PRINT "STRUCTURE RUN. THEN THE PROGRAM FITS A"
260 PRINT "STRAIGHT LINE TO THE RECORDED DATA BY A"
270 PRINT "LINEAR REGRESSION USING THE METHOD OF"
280 PRINT "LEAST SQUARES. BASED ON THE LINE IN"
290 PRINT "SPACE REPRESENTED BY THE LINEAR REGRES-
300 PRINT "SION AND ITS ANGLE TO THE HORIZONTAL."
310 PRINT "THE PROGRAM CALCULATES WHERE TO MOVE"
320 PRINT "THE RTT TO ALIGN IT TO THE LINEAR RE-
330 PRINT "GRESSION IN SPACE. THIS PROVIDES THE"
340 PRINT "A CONSTANT VIEWING ANGLE TO OBSERVE THE"
350 PRINT "GLIDE PATH AND MEASURE ITS STRUCTURE"
360 PRINT "PERFORMANCE.": PRINT "": PRINT ""
370 PRINT "PRESS ANY KEY TO CONTINUE.": CALL - 755: HOME
380 PRINT "NOW, HOW TO USE THE PROGRAM.": PRINT ""
390 PRINT "FIRST, YOU WILL BE ASKED FOR SOME VARI-
400 PRINT "ABLES WHICH TAILOR THE CALCULATIONS TO"
410 PRINT "THE FACILITY BEING CHECKED."
420 PRINT "THEN, YOU PUT IN X AND Y COORDINATES OF"
430 PRINT "DATA POINTS FROM THE STRUCTURE RUN. YOU"
440 PRINT "SELECT YOUR X-AXIS, SUCH AS SECONDS,"
450 PRINT "NAUTICAL MILES, ETC. THE Y COORDINATES"
460 PRINT "ARE LIGHT LINE VALUES ON THE RECORDING."
470 PRINT "90 HZ READINGS ARE NEGATIVE: 150 HZ "
480 PRINT "READINGS ARE POSITIVE.": PRINT ""
490 PRINT "PRESS ANY KEY TO CONTINUE. ": CALL - 756: HOME
500 PRINT "PRESS <S> TO STOP ENTERING COORDINATES."
510 PRINT "ONCE YOU VERIFY YOUR COORDINATES ARE"
520 PRINT "CORRECT, THE PROGRAM WILL CALCULATE AN"
530 PRINT "EQUATION FOR THE LINEAR REGRESSION. IT"
540 PRINT "WILL ALSO PROVIDE A TERM CALLED THE"
550 PRINT "COEFFICIENT OF DETERMINATION, WHICH"
560 PRINT "LETS YOU KNOW HOW WELL THE LINEAR RE-
570 PRINT "GRESSION FITS YOUR DATA. THE CLOSER "
580 PRINT "THE COEFFICIENT IS TO 1, THE BETTER THE"
590 PRINT "FIT. YOU WILL ALSO GET THE AVERAGE Y"
600 PRINT "VALUE FOR COMPUTING THE AVERAGE GLIDE"
610 PRINT "ANGLE.": PRINT ""
620 PRINT "PRESS ANY KEY TO START.": CALL - 756
630 X1 = 0: Y1 = 0: X2 = 0: Y2 = 0: P = 0: A1 = 0: A2 = 0
640 HOME: PRINT "DO YOU WANT.": PRINT ""
650 HTAB 5: PRINT "1) ENTER NEW DATA": HTAB 5: PRINT "2) GET DATA FROM DISK": HTAB 5: PRINT "3) CATALOG DISK": PRINT ""
660 PRINT "WHICH CHOICE? ": GET A$: IF VAL (A$) = 1 OR VAL (A$) = 3 GOTO 1110

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ATTACHMENT 10

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112 IF VAL A$ = 1 GOTO 1150
113 IF VAL A$ = 2 GOTO 1130
114 PRINT : HOME : GOSUB 1260: PRINT D$: "CATALOG": PRINT CHR$(4); "END006": CALL - 75c: GOTO 1080
115 HOME : PRINT "FACILITY VARIABLES:" : PRINT ""
116 INPUT "FACILITY LOCATION: "; F$: PRINT ""
117 INPUT "RUNWAY NUMBER: "; R$: PRINT ""
118 INPUT "6/S OFFSET DISTANCE: "; OFF: PRINT ""
119 INPUT "5/S-THRESHOLD DISTANCE: "; DTH: PRINT ""
120 INPUT "RTT EYEPiece ANGLE: "; EYE: PRINT ""
121 INPUT "TERRAIN SLOPE IN DEGREES: "; S: PRINT ""
122 INPUT "REMARKS ( 40 CHAR.): "; R$: PRINT ""
123 PRINT " IS THE DATA CORRECT? "; GET Y$
124 IF Y$ = "Y" THEN GOTO 1260: IF Y$ < "N" GOTO 1270
125 GOTO 1150
126 HOME : PRINT "REMEMBER THESE POINTS:" : PRINT ""
127 PRINT "NOTE YOUR X COORDINATES FOR POINTS A "
128 PRINT "AND B. Y VALUES ARE IN LIGHTLINES."
129 PRINT "IF YOU ARE READY, PRESS ANY KEY.": CALL - 75c
130 HOME
131 X = X0 = 0: Y0 = 0: X2 = 0: Y2 = 0: P = 0: A1 = 0: A0 = 0
132 P = P + 1.
133 PRINT "X "; P: " COORDINATE IS: "; INPUT Z$
134 IF Z$ = "S" THEN GOTO 1370
135 DX(P) = VAL (Z$)
136 PRINT "Y "; P: " COORDINATE IS: "; INPUT Y: DY(P) = Y: PRINT "": GOTO 1320
137 HOME : PRINT "YOUR DATA PAIRS ARE:" : PRINT "": Q = 0
138 PRINT "NUMBER", "X", "Y"
139 FOR I = 1 TO P - 1: Q = Q + 1: PRINT I, DX(I), DY(I)
140 IF Q = 20 THEN GOTO 1420
141 GOTO 1440
142 PRINT "PRESS ANY KEY TO CONTINUE. ": CALL - 75c
143 Q = Q - 20: HOME : PRINT "NUMBER", "X", "Y": PRINT " "
144 NEXT I: PRINT ""
145 PRINT "ARE ALL YOUR DATA PAIRS CORRECT? "; GET Y$: PRINT ""
146 IF Y$ = "Y" THEN GOTO 1500: IF Y$ < "N" GOTO 1450
147 INPUT "ENTER # OF INCORRECT PAIR: "; N: PRINT ""
148 PRINT "X IS "; DX(N): " AND Y IS "; DY(N): PRINT ""
149 INPUT "CHANGE X COORDINATE TO: "; DX(N): INPUT "CHANGE Y COORDINATE TO: "; DY(N): GOTO 1370
150 PRINT "": PRINT "X-COORDINATE FOR POINT A IS: "; XA: PRINT "X-COORDINATE FOR POINT B IS: "; XB
151 PRINT "": PRINT "ARE THESE CORRECT?": GET Y$: IF Y$ = "Y" GOTO 1550
152 IF Y$ < "N" GOTO 1510
153 PRINT "": INPUT "CHANGE POINT A X-COORDINATE TO: "; XA: INPUT "CHANGE POINT B X-COORDINATE TO: "; XB: PRINT " "
154 GOTO 1500
155 PRINT "": PRINT "DO YOU WISH TO SAVE THE RAW DATA": PRINT "TO DISK?": GET Y$
156 IF Y$ = "Y" GOTO 2410: IF Y$ < "N" GOTO 1550
157 HOME : PRINT "HERE COMES THE LINEAR REGRESSION!": FOR II = 1 TO 500: NEXT II: PRINT ""
158 P = P - 1
159 FOR I = 1 TO P: X0 = X0 + DX(I): Y0 = Y0 + DY(I): XY0 = XY0 + (DX(I) * DY(I))
160 X2 = X2 + (DX(I) ^ 2): Y2 = Y2 + (DY(I) ^ 2): NEXT I
161 A1 = (XY0 - (X0 * Y0 / P)) / (X2 - (X0 ^ 2 / P))
162 A0 = (Y0 / P) - (A1 * X0 / P)
163 R = (Y0 - (X0 * Y0 / P)) ^ 2 / ((X2 - (X0 ^ 2 / P)) * (Y2 - (Y0 ^ 2 / P)))
164 AVG = Y0 / P
165 REM SPEW FORTH LINEAR REG RESULTS.
166 HOME : PRINT "THE LINEAR EQUATION IS:": PRINT ""
167 HTAB 10: PRINT "Y = A1(X) + A0": PRINT ""
168 PRINT "WHERE": PRINT "": HTAB 20: PRINT "A1 = "; A1: HTAB 20: PRINT "A0 = "; A0: PRINT ""

```

ATTACHMENT 10

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100 PRINT "COEFF OF DETERMINATION = ";R; PRINT ""
110 HOME : PRINT "AVERAGE OF X VALUES = ";AVG; PRINT ""
120 HOME : PRINT "NUMBER OF DATA PTS. = ";P; PRINT ""
130 PRINT "DO YOU WANT TO CALCULATE OTHER POINTS?"
140 PRINT "USING THE LINEAR REGRESSION EQUATION? "; GET Y$; PRINT : IF Y$ < "Y" AND Y$ > "N" GOTO 1720
150 IF Y$ = "Y" THEN GOTO 1760
160 GOTO 1800
170 PRINT "X COORDINATE IS: ";XX
180 YY = (A1 * XX) + A0; PRINT "Y COORDINATE IS: ";YY
190 PRINT "DO YOU WANT MORE? "; GET Y$; PRINT ""
200 IF Y$ = "Y" THEN GOTO 1760; IF Y$ = "N" GOTO 1780
210 PRINT "DO YOU WANT LINEAR REGRESSION DATA PRS."; PRINT "USING YOUR X COORDINATES?"; GET Y$; PRINT : IF Y$ < "Y" AND Y$ > "N" GOTO 1800
220 IF Y$ = "Y" THEN GOTO 1830
230 GOTO 1910
240 HOME : PRINT "LINEAR REGRESSION DATA PAIRS:"; PRINT ""
250 PRINT "X", "Y"; PRINT "W = 0"
260 FOR J = 1 TO P: W = W + 1; PRINT DX(J), A0 + (A1 * DX(J))
270 IF W = 20 THEN GOTO 1880
280 GOTO 1900
290 PRINT "PRESS ANY KEY TO CONTINUE."; CALL - 756; PRINT
300 W = W + 20; HOME : PRINT "X", "Y"; PRINT ""
310 NEXT J; PRINT ""
320 PRINT " "; PRINT "PRESS ANY KEY TO START CALCULATING THE"; PRINT "NEW RTT POSITION. "; CALL - 756
330 HOME : PRINT "GIVE ME A SECOND!"; FOR I = 1 TO 500; NEXT I: CN = 0.017453286
340 DA = SQR ((DOFF * 2 + ((DTH + 24304) * 2))
350 LB = SQR ((DOFF * 2 + ((DTH + 3500) * 2))
360 YA = A1 * XA + A0; YB = (A1 * XB) + A0
370 AA = CN * (YE + (YA * 0.7 / 40)); AB = CN * (YE + (YB * 0.7 / 40))
380 LI = ATN ((DA * TAN (AA)) - (DB * TAN (AB))) / 20804
390 RI = DB * (1 - TAN (AB) / TAN (LIN))
400 SR = P * CN: RTT = RI * (SIN (LIN) / SIN (LIN - SR))
410 REM SPEW PLACEMENT RESULTS.
420 HOME : PRINT "*****"
430 INVERSE : PRINT "RTT PLACEMENT ANALYSIS FOR: NORMAL
440 PRINT "S: " : R/W : RMS; PRINT RMS
450 PRINT "*****"; PRINT ""
460 HTAB 5; PRINT "RTT EYEPIECE ANGLE: ";EYE
470 HTAB 4; PRINT "G/S OFFSET DISTANCE: ";DOFF
480 PRINT "G/S-THRESHOLD DISTANCE: ";DTH
490 HTAB 2; PRINT "TRN SLOPE IN DEGREES: ";S
500 HTAB 3; PRINT "EYE ANGLE TO POINT A: ";AA / CN
510 HTAB 3; PRINT "EYE ANGLE TO POINT B: ";AB / CN
520 HTAB 7; PRINT "N OF DATA POINTS: ";P
530 HTAB 3; PRINT "LIN REGRESSION ANGLE: ";LIN / CN
540 HVA = EYE + (AVG * 0.7 / 40)
550 HTAB 10; PRINT "AVERAGE ANGLE: ";AVA
560 PRINT " "; PRINT "*****"
570 HTAB 11; PRINT "MOVE THE RTT "; INT (RTT * 10) / 10; " FEET."
580 PRINT "*****"; PRINT ""
590 PRINT "NEGATIVE VALUE MEANS MOVE TOWARD G/S;"
600 PRINT "POSITIVE VALUE MEANS MOVE TOWARD RNWY."
610 PRINT "ANOTHER ANALYSIS? "; GET Y$; PRINT : IF Y$ < "Y" AND Y$ > "N" GOTO 2200
620 IF Y$ = "Y" GOTO 1080
630 HOME : PRINT "INSERT PROGRAM DISK AND PRESS"; PRINT "ANY KEY"; CALL - 756
640 PRINT "DS = "; REM CTRL D.
650 PRINT "S"; "RUN MENU"

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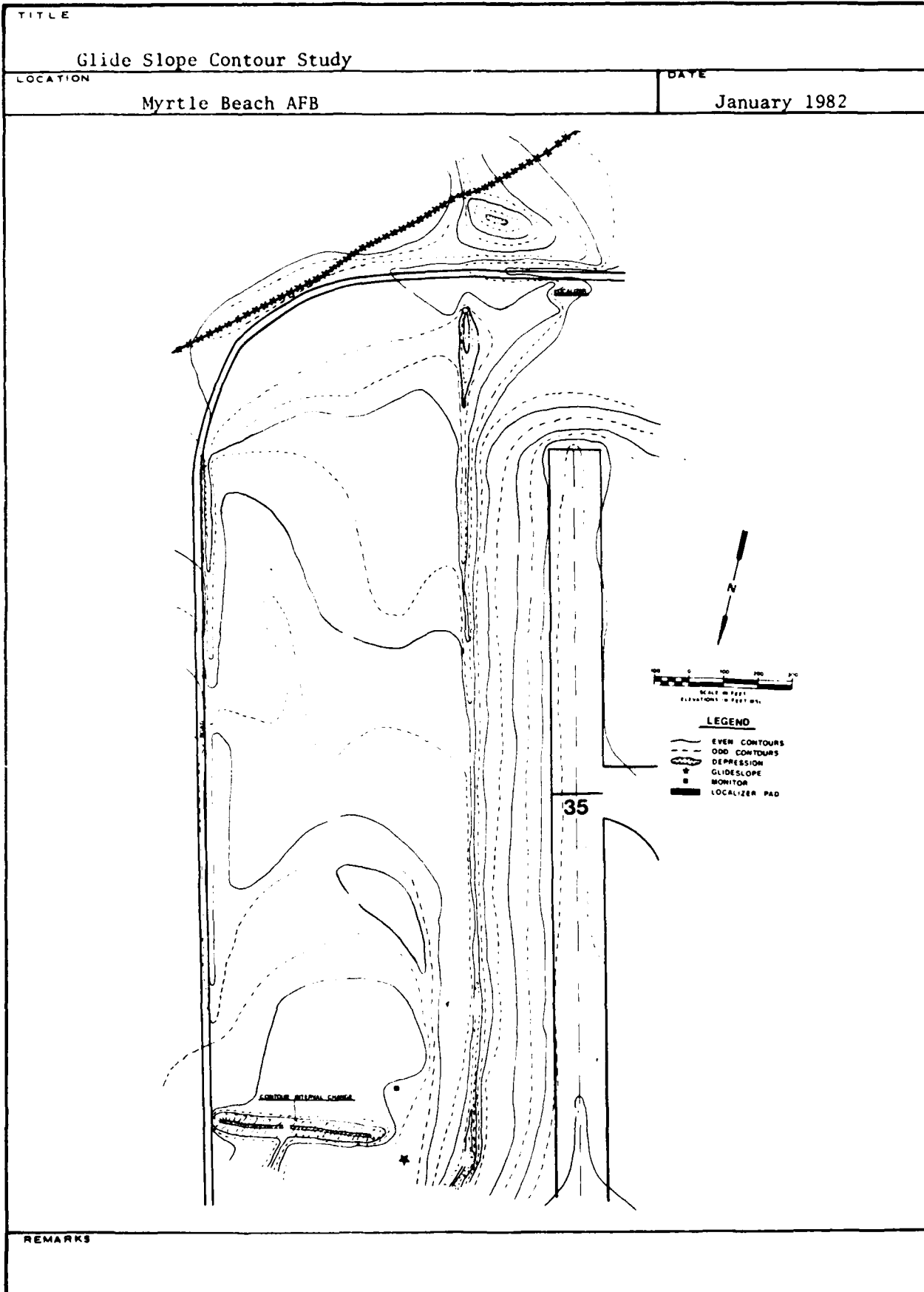
ATTACHMENT 10

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2250 END
2260 PRINT "": PRINT "INSERT DATA DISK AND PRESS ANY KEY. : CALL - 756: RETURN
2270 PRINT D$;"CLOSE RTT " : LEFT$ (F$,8); " R/W ";RW$;" " : LEFT$ (RM$,9); POKE 216,0: RETURN
2280 REM GET DATA.
2290 ONERR GOTO 2510:ZIP = 1
2300 HOME : INPUT "FACILITY LOCATION: ";F$: PRINT ""
2310 INPUT "RUNWAY NUMBER: ";RW$: PRINT ""
2320 INPUT "REMARKS (<40 CHAR.): ";RM$: PRINT ""
2330 GOSUB 2260
2340 HOME : VTAB 10: PRINT "GETTING " : INVERSE : PRINT "RTT " : LEFT$ (F$,8); " R/W ";RW$;" " : LEFT$ (RM$,9); NORMAL : PRINT
" FILE."
2350 PRINT D$;"READ RTT " : LEFT$ (F$,8); " R/W ";RW$;" " : LEFT$ (RM$,9)
2360 INPUT P: INPUT DOFF: INPUT DTH: INPUT EYE: INPUT S
2370 INPUT F$: INPUT RW$: INPUT RM$
2380 FOR I = 1 TO P - 1: INPUT DX(I): INPUT DY(I): NEXT I
2390 INPUT XA: INPUT XB
2400 GOSUB 2270: GOTO 1370
2410 PRINT "": REM SAVE DATA.
2420 GOSUB 2260: ONERR GOTO 2510:ZIP = 2
2430 HOME : VTAB 10: PRINT "SAVING " : INVERSE : PRINT "RTT " : LEFT$ (F$,8); " R/W ";RW$;" " : LEFT$ (RM$,9); NORMAL : PRINT
" FILE."
2440 PRINT D$;"OPEN RTT " : LEFT$ (F$,8); " R/W ";RW$;" " : LEFT$ (RM$,9)
2450 PRINT D$;"WRITE RTT " : LEFT$ (F$,8); " R/W ";RW$;" " : LEFT$ (RM$,9)
2460 PRINT P: PRINT DOFF: PRINT DTH: PRINT EYE: PRINT S
2470 PRINT F$: PRINT RW$: PRINT RM$
2480 FOR I = 1 TO P - 1: PRINT DX(I): PRINT DY(I): NEXT I
2490 PRINT XA: PRINT XB
2500 GOSUB 2270: GOTO 1570
2510 PRINT "": PRINT "BAD TRANSFER OF DATA!!! : PRINT "": FOR I = 1 TO 1000: NEXT I: POKE 216,0
2520 IF ZIP = 2 GOTO 2500
2530 GOSUB 2270: GOTO 1080

```

ATTACHMENT 11



TITLE: GLIDE SLOPE CONTOUR STUDY

LOCATION: Duke Field, Eglin Auxiliary 3

DATE: March 1982

CONTOUR INTERVAL CHANGE →

BRUSH & TREES

BRUSH & TREES

8

1

100 **0** **100** **200** **300**

SCALE IN FEET
ELEVATIONS IN FEET MSL

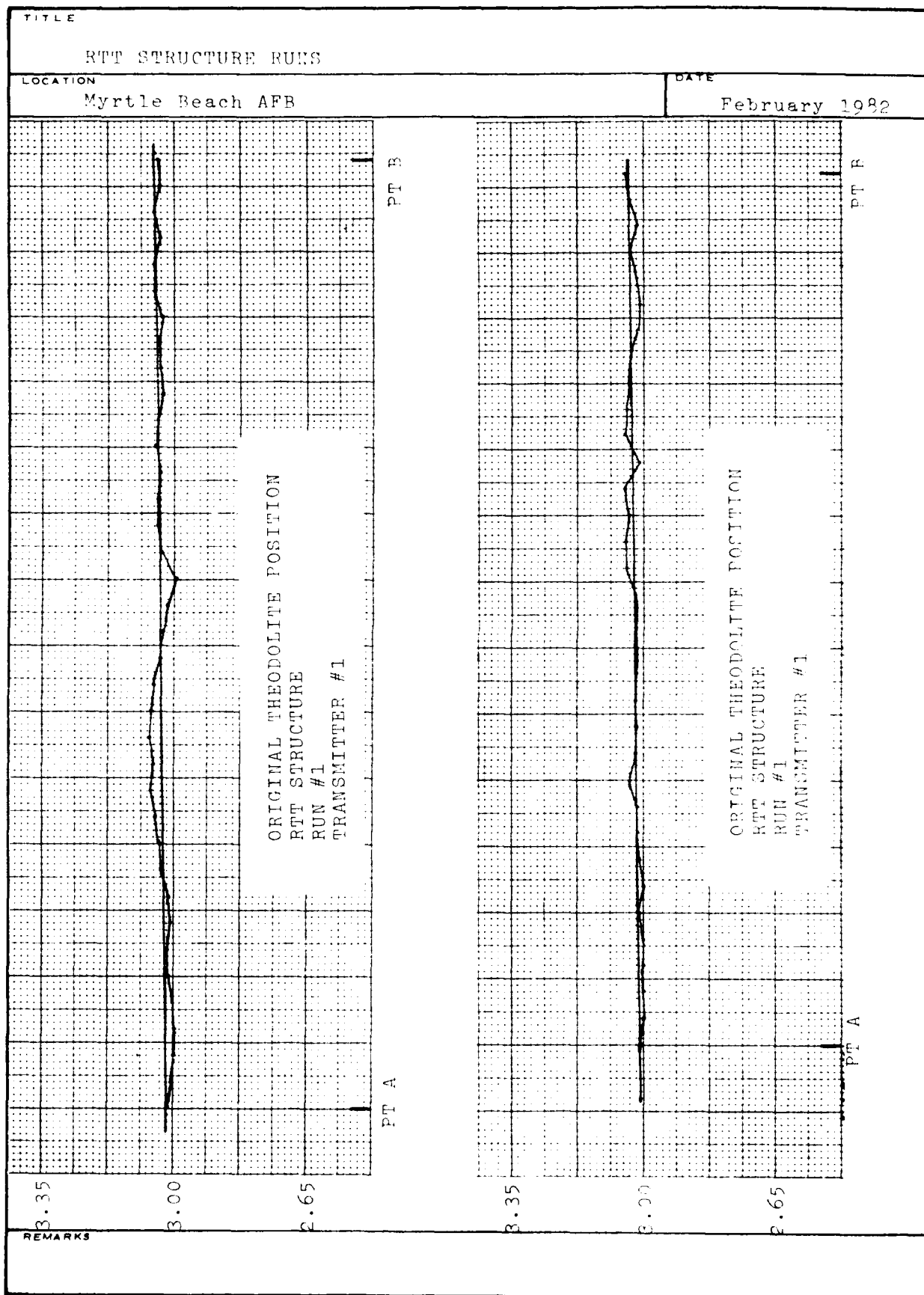
LEGEND

- EVEN CONTOURS
- - - ODD CONTOURS
- ⬮ DEPRESSION
- ★ GLIDE SLOPE

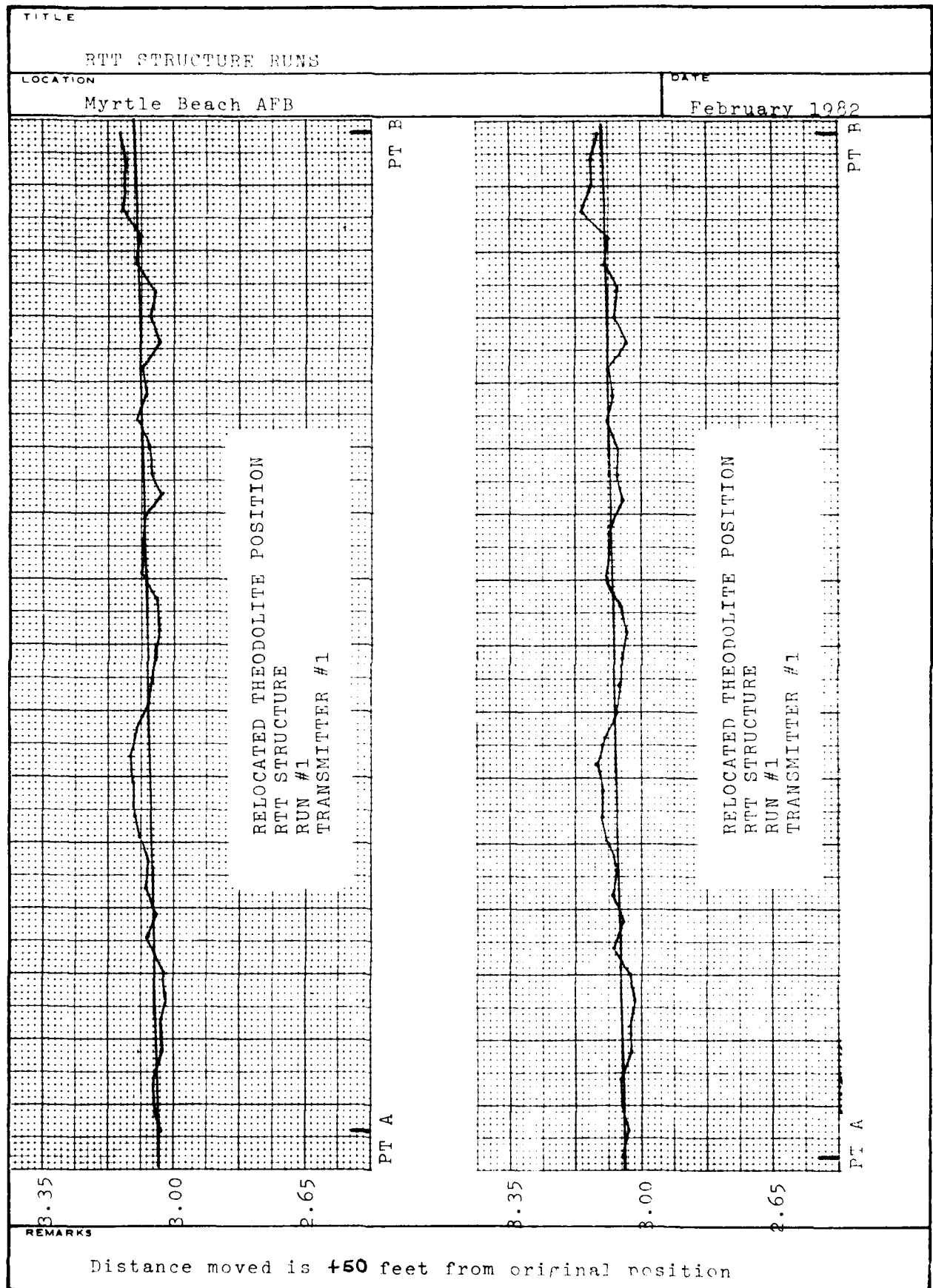
GLIDE SLOPE

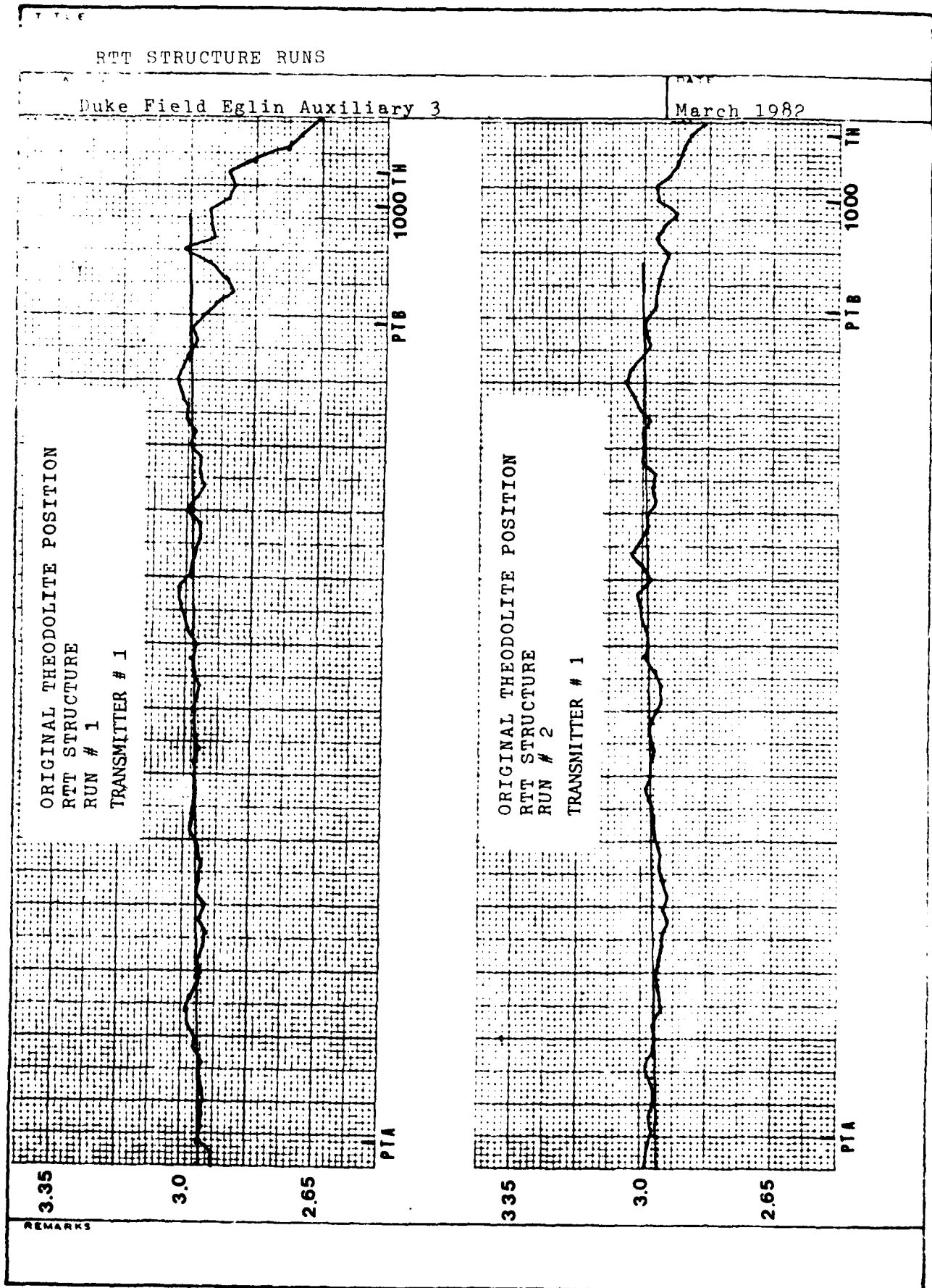
The figure is a topographic map titled "GLIDE SLOPE CONTOUR STUDY" for "Duke Field, Eglin Auxiliary 3" dated "March 1982". The map displays contour lines representing elevation in feet MSL. A rectangular area on the left is divided into two sections labeled "8" and "1". A "GLIDE SLOPE" is indicated by a star symbol at the bottom center. A scale bar at the bottom right shows distances from 100 to 300 feet. A legend defines symbols for even contours (solid line), odd contours (dashed line), depressions (inverted triangle), and glide slopes (star). A north arrow is located on the right side. A "CONTOUR INTERVAL CHANGE" is indicated by an arrow pointing to a specific contour line. "BRUSH & TREES" are marked with wavy lines on the right side of the map.

ATTACHMENT 12



ATTACHMENT 12





ATTACHMENT 12

